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Bureau of Mines Information Circular/1987

Bureau of Mines Cost Estimating System Handbook

(In Two Parts)
1. Surface and Underground Mining

Compiled by Staff, Bureau of Mines

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Bureau of Mines Cost Estimating System Handbook

(In Two Parts)
1. Surface and Underground Mining

Compiled by Staff, Bureau of Mines

UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
David S. Brown, Acting Director

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FOREWORD

Need for the Handbook

A computerized mineral inventory system to help the United States Government appraise critical shortages of materials has been eatablished. This involves evaluation of mineral deposits using the Bureau of Mines Minerals Availability System (MAS). The MAS is concerned with costing mineral occurrences where it is unknown, if they can be mined and/or processed at a profit. Therefore a consistent functional method of costing both mining and mineral processing is a requirement of the financial analysis phase of MAS. The objective of this handbook is to develope a manual method for preparation of feasibility type estimates for capital and operating costs of mining and primary mineral processing of various types of mineral occurrences using state-of-the-art technology.

Use of the Handbook

This handbook has been developed for a user with knowledge and experience in both mining and estimating procedures. The user should not use this handbook to try to determine the cost of any single component of a mining or mineral processing system. The combination of components will produce a reliable feasibility type estimate which should fall within 25 percent of expected actual cost. The estimated values from the use of the handbook are not intended to duplicate any specific mineral producer's capital or operating costs. Individual component costs may vary.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

bank m^3	bank cubic meter	lb	pound
cm	centimeter	lb/ft^2	pound per square foot
°C	degree Celsius	lb/ft^3	pound per cubic foot
°F	degree Farenheit	lb/gal	pound per gallon
ft	foot	m	meter
gal	gallon	m/d	meter per day
gal/d	gallon per day	m/min	meter per minute
h	hour	m/yr	meter per year
h/d	hour per day	m^3	cubic meter
ha	mectare	m^3/d	cubic meter per day
ha/d	hectare per day	m^3/h	cubic meter per hour
hp	horsepower	m^3/m	cubic meter per meter
Hz	hertz	m^3/mt	cubic meter per metric ton
in	inch	m^2	square meter
kg	kilogram	mg/L	milligram per liter
kg/cm^2	kilogram per square centimeter	mtpd	metric ton per day
		mtph	metric ton per hour
kg/m^3	kilogram per square meter	mt·km	metric ton kilometer
kg/ha	kilogram per hectare	mt/m^3	metric ton per cubic meter
kg/mt	kilogram per metric ton	mi/d	mile per day
km	kilometer	mi/gal	mile per gallon
km/d	kilometer per day	mph	mile per hour
km^2	square kilometer	MPa	megapascal
km^2/d	square kilometer per day	MV·A	megavolt ampere
kPa	kilopascal	MW	megawatt
kV	kilovolt	Pa	pascal
kV·A	kilovolt ampere	psi	pound per square inch
kW	kilowatt	st	short ton
kW·h	kilowatt hour	yd^3	cubic yard
L/s	liter per second	yr	year
$(L/s)/m^2$	liter per second per square meter	V	volt

BUREAU OF MINES COST ESTIMATING SYSTEM HANDBOOK

(In Two Parts)

1. Surface and Underground Mining

Compiled by Staff, Bureau of Mines

ABSTRACT

This Bureau of Mines report and its companion report (Information Circular 9143) have been prepared to assist in the preparation of prefeasibility type estimates for capital and operating costs of mining of various types of mineral occurrences using current technology. The handbook provides a convenient costing procedure based on the summation of the costs for the unit processes required in any particular mining or mineral processing operation.

The costing handbook consists of a series of costing sections, each corresponding to a specific mining unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate, in January 1984 dollars, costs through the use of either costing curves or formulae representing the prevailing technology.

Coverage for surface mining includes dredging, quarrying, strip mining, and open pit mining. The underground mining includes individual development sections for drifting, raising, shaft sinking, stope development, various mining methods, underground mine haulage, general plant, and underground mine administrative cost. This system can be used for estimating cost data for an undeveloped deposit or for checking or verifying mining costs from a developed deposit, with a minimum amount of background information.

INTRODUCTION

The Interior Department's Bureau of Mines systematically measures and classifies identified domestic and foreign mineral resources according to their respective extraction technologies, economics, and commercial availability. To this end, the Bureau collects data on major mines and deposits worldwide and uses these data in estimating and monitoring production costs and availabilities for 34 strategic mineral commodities. The estimation of production costs includes such items as capital expenditures and operating costs for mining and mineral processing operations, as well as transportation and infrastructure costs. A consistent method of costing is a requirement for such analysis. The cost estimation system (CES) has proven invaluable to the Burea's work in this area.

The CES handbook was developed in 1975 to assist in the preparation of prefeasibility type estimates for capital and operating costs of mining and beneficiation of various types of mineral occurrences using current technology. The system provided a convenient costing procedure based on the summation of the costs for the unit processes required in any particular mining or mineral processing operation. This edition of the handbook is essentially a revision of the earlier effort, updated to reflect the costs of technologies employed as of January 1984. To provide continuity, the numbering system used in the original handbook has been retained.

The following are the 34 strategic commodities targeted for coverage by the updated costing handbook.

Aluminum
Antimony
Asbestos
Barium
Beryllium
Chromium
Cobalt
Columbium
Copper
Fluorspar
Gold
Graphite
Hafnium
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphate
Platinum
Potash
Rare earths
Silver
Sulfur
Tantalum
Thorium
Tin
Titanium
Tungsten
Zinc
Zirconium

The updated edition of the CES handbook consists of this Information Circular (IC) on surface and underground mining, and IC 9143 on mineral processing.

EVOLUTION OF CES

The first edition of the Bureau's Capital and Operating Cost Estimating System Handbook was prepared by STRAAM Engineers, Inc., Mining Division, under contract J0255026. The handbook was developed for use by individuals with knowledge and experience in both mineral engineering and cost estimation. The handbook was designed to produce a reliable prefeasibility type estimate, acurate to within 25% of the expected actual cost.

The first edition was introduced in 1975 and, accordingly, the costs therein reflected 1975 technology. In the decade since the introduction of the handbook, considerable technological change has taken place and mining mineral processing costs have been significantly affected. Further, other important developments such as decreasing metal prices, rising labor costs, and environmental restraints have resulted in a series of austerity measures effected by the management of many mineral operations. In view of these considerations, a complete revision of the handbook was warranted.

In order to ensure adequate coverage of the 34 strategic commodities by the CES, it was necessary to reevaluate each cost section from the 1975 version of CES and also to develop a considerable number of new unit process sections. The task of updating and revising the manual was assigned primarily to three Bureau groups. The Intermountain Field Operations Center (Denver, CO) was assigned the responsibility of providing updated replacement sections for the majority of the surface mining and mineral processing unit operations contained in the original manual, while the Western Field Operations Center (Spokane, WA) held primary responsibility for updating and supplementing the sections for underground mining. Additionally, several new mineral processing unit operations were provided by both field centers. Finally, 29 completely new unit operations were prepared by Pincock, Allen and Holt, Inc., under contract J0245002. The entire update project was coordinated by the Minerals Availability Field Office (Denver, CO).

The CES handbook consists of a series of costing sections, each corresponding to a specific mining or mineral processing unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate costs through the use of either costing curves or formulas, depending on the option of the estimator. The cost curves are typically presented on a logarithmic scale of cost versus capacity and the corresponding cost formulas are (usually) of the form $Y = A(X)^B$, where X and Y represent the independent and dependent variables of size or capacity and cost, respectively. All cost estimation methodologies contained in this manual have been prepared in January 1984 dollars and represent the prevailing technology at that date.

In the operating cost formulas and graphs presented for the various unit processes throughout this handbook, the Y subscripts L, S, and E indicate labor, supplies, and equipment operation, respectively. None of the curves or equations in this handbook contain allowances for property and/or inventory taxes, general insurance, or depreciation.

The reader will note that all cost equations and curves are linear, logarithmic, or exponential, and that associated with each cost section is a range of applicability. The data obtained within these stated limits are reliable, but the same cannot be said for costs obtained by extrapolation outside of these limits. In most cases, the upper and lower limits encompass production parameters for actual mining and mineral processing operations used in the preparation of the unit process sections with values beyond tending to fall outside the range of current technology.

The data used in the development of this handbook were derived from information gleaned from a number of sources including industry contacts, Bureau equipment suppliers and vendors, files, and Government contractors. The major steps involved in the development were essentially the same for all unit processes and involved the following progression:

1. Accumulation of data relating to each unit process through literature review, industry contacts, equipment vendors, etc. to provide the data base for development of the capital and operating cost estimates.

2. Determination of the types of the equipment for the unit process used in industry as of January 1984, and the establishment of the range of capacities for which the unit process is employed.

3. Selection of a minimum of three capacity data points for detailed cost analysis and subsequent preparation of a bottom-up cost estimate for each data point. The majority of the data points corresponded to a capacity of an existing operation. In isolated cases where an existing operation of appropriate capacity could not be located, or because of insufficient data, the costs for an operation were modeled from the other estimates. In all cases, the limits of applicability stated for each section are within 15% of the maximum and minimum data points, respectively.

4. Calculation of the costing formulas and drafting of the cost curves. Generally, the costing formulas were derived through geometric regression analysis of the cost estimates prepared for each capacity, although a few curves are linear or exponential.

5. Verification of the cost formula through comparison with actual data. The total facility costs projected by the handbook have been demonstrated to fall within the limits of a prefeasibility estimate (i.e., within plus or minus 25% of actual costs).

METHODOLOGY

The CES handbooks for surface and underground mining and mineral processing are each divided into three major sections. The first of these sections, capital costs, involves the construction of the mine or mineral processing facility. The second section, operating costs, allows for the computation of the operating labor, supplies, and equipment operation of an existing or hypothetical operation. The last section, infrastructure, contains cost equations and curves for an assortment of infrastructure items.

Each cost generated by use of the costing handbook may be broken down into its respective subcomponents. A brief discussion on this aspect of the costing system, as applied to capital and operating costs, follows.

Capital Cost

The capital cost estimates were prepared to correspond to the actual range of capacities for which the unit processes are employed in industry. Detailed cost estimates were prepared for a minimum of three separate capacities covering this range. For the capital cost estimates, each unit process estimate was composed of the construction labor cost, the construction materials cost, a purchased equipment cost, and the cost of transportation. Each capital cost section gives a breakdown of these four components as a percentage of the total fixed capital cost for the unit process.

Modest contingencies, generally ranging from 5% to 10%, were applied to cover incidental items not specifically addressed in the estimates for some of the capital cost sections. However, it must be stressed that this contingency was applied only in areas where there was a degree of uncertainty on the part of the evaluator preparing the cost section and it must not be inferred that an overall blanket contingency has been applied.

Construction Labor

Construction labor costs were estimated from worker-hour requirements for each unit operation for each capacity studied. Average labor costs were determined from local union wage rates for a variety of job classifications common to mineral industry construction. The average labor wage rates applied to the worker-hour estimates include labor burden and fringe benefits of 21% of the base wage rate. For this analysis, the construction labor burden and fringe benefits have been assumed to include the employer's contribution to union funds for health and welfare, vacations, holidays, sick leave, retirement, Social Security (FICA), Federal Unemployment Insurance, (FUI), State Unemployment Insurance (SUI), and Workmen's Compensation.

A shift adjustment factor has been included in some of the capital cost estimation sections for mining, since it is conceivable that certain operations may operate either one or three shifts per day. Since the base case sections were designed for two-shift-per-day operation, it was necessary to include a mechanism for adjusting the cost per day total for an alternative operating schedule. The job classifications and associated base wage rates used in the computation of the construction labor component of the capital costs are presented in table 1.

Table 1.--Construction labor job classifications and hourly wage rates

Job	Wage[1]
Boilermaker, journeyman	$21.00
Boilermaker, apprentice	17.32
Carpenter, journeyman	20.50
Carpenter, apprentice	15.89
Concrete finisher, journeyman	21.40
Concrete finisher, apprentice	15.88
Electrician, journeyman	23.11
Electrician, apprentice	12.71
Equipment operator	19.15
Equipment operator, apprentice	15.80
Ironworker, journeyman	22.08
Ironworker, apprentice	16.01
Laborer	12.71
Millwright, journeyman	22.52
Millwright, apprentice	17.27
Painter, journeyman	19.23
Painter, apprentice	14.34
Pipefitter, journeyman	20.90
Pipefitter, apprentice	13.71

[1] Includes 21% burden and fringe benefits.

Construction Materials

The estimates for construction materials include support steel, steel reinforcing bars, concrete, sand and gravel, timber, etc. Also included are small handtools, welding rods, and other miscellaneous equipment. It was generally assumed that construction materials are readily available at the mine or construction site and that the freight cost associated with these materials is negligible.

Purchased Equipment

In the capital cost sections for both mining and mineral processing unit operations, purchased equipment refers to the major mining or process equipment directly associated with the operation. The development of the capital cost estimates for each unit process included the construction of a major equipment lists with the equipment sized according to the capacities analyzed.

Transportation

Transportation, or freight, costs have been estimated using the basis of a midwestern (Denver, CO) mine or construction site. In most cases, freight costs were estimated using the nearest supplier-vendor for each piece of equipment to calculate the total distance for the shipment. Average transportation rates were then applied to the distance to calculate the cost of transporting the major equipment items from the manufacturer to the construction site. In each capital cost section, the percentage of the fixed capital cost for the particular unit operation is given and can be applied to the cost generated by the costing formulas (or curve) to derive the transportation cost.

A uniform 4% sales tax was applied to the total fixed capital cost for each unit operation. This approach reflects the construction of a green- field mine or mineral processing facility by an independent contractor. If the sales tax for the area being estimated differs from the standard 4%, then the appropriate adjustment to the total capital cost should be made.

Adjustment Factors

Many unit process sections contain one or more adjustment factors that may be used to address circumstances other than those assumed for the develop- ment of the cost section. These factors are generally multiplied by the product of the cost formula (or the cost taken directly from the curve) to obtain a cost representative of these special circumstances.

All curves in this handbook have been adjusted to a common base with every effort having been made to present data representative of a typical application of the particular mining method or beneficiation process under consideration. Often, however, the estimator will be privy to information that can substantially upgrade the quality of the estimate through the judicious application of adjustment factors. In order to properly apply the adjustment factors, the estimator must be capable of discerning any differences between the method or process under consideration and that presented in this handbook. When the estimator encounters an abnormal situation, proper adjustment of curve data, either upward or downward, must be made. For that reason, whenever certain adjustment factors may apply they have been explained and referenced. Mention of some of the common adjustment factors has been omitted from the narratives in order to avoid repetition. These factors include the various cost indexes and the labor rate and power cost conversion methods, as well as more subtle variables such as rock hardness. Even though many variables have been considered in the preparation of the handbook, every mineral deposit has its own unique differences that the individual estimator must be able to recognize and include in the cost estimation.

Operating Cost

The operating costs presented in these sections include the mining and mineral processing costs and mine or plant overheads. The operating cost section for each unit process includes distinct formulas and curves allowing for the independent calculation of the operating labor cost, the operating supplies cost, and the equipment operation cost. Fixed charges of insurance, taxes, royalties, depreciation, packaging, product freight, selling expense, and general and research expenses are not included. The costs associated with supervision are not included with the individual unit processes, but are included in aggregate form with the general and administrative expense curves.

Labor

The labor costs generated through the use of this handbook include both direct operating labor and maintenance labor. Each operating cost section of the handbook provides the relative percentages of direct and maintenance labor that may be applied to the aggregate operating labor cost generated by the costing formula.

The text also presents a tabulated summary of the direct labor component of the operating labor cost, providing a breakdown of job classification and the average wage rates for the direct labor involved in the operation. An example listing of job classifications and wage rates used in the estimation of the operating labor costs is presented in table 2.

Table 2.--Operating labor job classifications and hourly wage rates

Job	Wage[1]
Operations:	
Rotary drill operator	$16.78
Shovel operator	18.11
Truck driver	15.89
Cave miner	18.11
Production loader	16.33
Control room operator	17.23
Mill operator	16.78
Mill helper	13.66
Sampler	15.44
Mill laborer	11.68
Maintenance:	
Mechanic/welder "A"	16.78
Mechanic/welder "B"	16.33
Electrician	18.11
Instrumentation	18.11
Oiler	14.56
Machinist	17.32

[1] Includes 32% burden and fringe benefits.

All labor rates (costs) used in the preparation of curves are based on the Denver, CO, area as of January 1984, and include an approximate allowance of 32% to cover all applicable payroll burdens and fringe benefits. Shift differentials of $0.30 per hour for the second shift and $0.45 per hour for the third shift have been included in the labor estimates. Area and/or incentive bonus premiums are not included and the estimator's judgment must determine the application of adjustment factors for these items.

Supplies

The supplies portion of the operating cost sections is comprised of electrical power, natural gas, reagents and industrial chemicals, and other consumables. A standard sales tax of 4% was added to all nonfuel items. The costs in table 3, reflective of January 1984, were used in preparing the estimates of supply operating costs:

Table 3.--Base case supply costs

Commodity	Unit	Cost
Fuel Oil	gal	$ 1.00
Natural Gas	1,000 ft^3	3.20
Coal, 84%-subbituminous	st	25.00
Electricity	kW·h	0.05

Equipment Operation

Equipment operation costs are considered to include fuel, lubrication, repair parts, and tires for all process equipment related to the unit processes. The fuel costs used in the preparation of the cost estimates on which the equipment operation curves are based were those in effect in the Denver, CO area in January 1984. The gasoline and diesel fuel costs were both $1.00 per gallon. A standard sales tax of 4% was added to all nonfuel items.

To adjust fuel costs to more recent, local rates, the user should first obtain the percentage of the total equipment operation cost due to fuel, and then multiply that percentage, in decimal form, by the current cost per gallon of gasoline or diesel fuel.

Adjustment Factors

Similar to the capital cost sections, many operating cost sections contain adjustment factors to address operating circumstances other than those that were assumed for the development of the costing section. Again, these factors are generally multiplied by the product of the costing formula (or the cost taken directly from the curve) to obtain a cost representative of these special circumstances. A more detailed explanation of the development and use of adjustment factors has been included in the previous discussion of capital costs.

Infrastructure

In addition to the unit process modules, a number of auxiliary sections representing the various infrastructure elements associated with mining and mineral processing operations have also been provided. These sections include long-distance transportation, loading facilities, storage, waste water treatment, access roads, townsite and camp operation, among others. The application of these sections is virtually the same as for the unit process sections.

COST UPDATING

The mining and mineral processing estimating procedures presented in the handbook, using individual cost component breakdowns, provide a methodology by which the base costs derived from the system can be adjusted to be applicable in different locations and/or be updated through time. Labor productivities can also be adjusted to reflect cost differences due to differences in manpower requirements.

Two methods may be used to adjust the labor cost curves. Method one, the more accurate of the two, is to use the prevailing labor rates for the area under consideration, in the year of desired escalation, and apply the appropriate payroll burdens and premiums. By dividing the new rate by the one given in the narratives, a labor adjustment multiplier is obtained, which is applied to the labor cost calculated from the formulas or from the curves. The second method is to use a labor rate for the area under consideration, in the base year. By dividing the new rate by the one given in the narrative, a labor adjustment multiplier is obtained, which is updated from either labor index number 1 or 2 (table 4). By dividing the index corresponding to the year of desired escalation by the one in January, 1984, a ratio is derived, which when combined with the labor adjustment multiplier is applied to the calculated labor cost. This factor can be used for all classes of labor throughout the estimate.

Operating cost differences due to varying productivities can be adjusted through the individual unit process labor costs or through the combination of the components of underground mining, surface mining, or mineral processing. Contained in the labor portion of the narrative of each unit operation is a weighted average labor rate of all laborers necessary for that particular unit operation. The number of workers per day for each unit operation can be calculated by dividing the daily adjusted base year labor cost by the product of the average labor rate and 8 h per shift. An adjustment can be made on each unit operation if the estimator replaces the number of workers per day calculated above with a new estimate and multiplies by the average labor rate times 8 to derive the new adjusted labor cost based on a new productivity. If specific information is not available on each unit operation, the user can compute the number of workers per day for each unit operation and add them to get the total workers for the mine or mineral processing plant being evaluated. A productivity ratio is determined by dividing the known number of workers per day by the computed value, which when multiplied by the total adjusted labor cost gives the new labor cost.

Often, productivities are expressed as metric tons per worker-shift or metric tons per worker-hour. If the previous calculation is carried further by introducing the capacities of the mines or processing plants, productivity ratios can be derived to adjust the labor costs.

Most of the supplies and equipment operation costs are composed of more than one component. In these cases, it is necessary to calculate the component cost for each index classification. By dividing the index corresponding to the year of desired escalation by the one for January 1984, for each component, a ratio is obtained that is multiplied by the calculated cost component. Combining these escalated components produces a final updated cost.

Electricity, natural gas, propane, and water costs do not have corresponding index classifications for updating. The method used to update these categories by location is to use the prevailing rates for the area under consideration, either in the base year or the year of desired escalation, and to divide the new rate by the one given in the narratives resulting in the adjustment factor. This factor is next multiplied by the corresponding cost from the curve to obtain the site-specific cost.

Cost Indexes

The mining wage rates index includes both mine and plant labor. This index includes skilled, unskilled, local, and expatriate labor along with burden and fringe benefits (employer's contribution to union funds for health and welfare, vacations, holidays, sick leave and retirement, Social Security, Federal and State Unemployment Insurance, and Workmen's Compensation).

The construction wage rate index includes all labor (see mining wage index for inclusions) employed in the construction of mines and mineral processing facilities.

The equipment and repair parts index relates to equipment and repair parts relevant to mining and mineral processing operations and related infrastructure, e.g., front-end loaders, shovels, load-haul-dumps (LHD's), trucks, jumbo drills, as well as crushers, grinding mills, flotation cells, thickeners, filters, etc.

The drill bits and related steel index includes steel for mining and mineral processing such as drill bits, pipe, fan liners, track, shovel and loader teeth and liners, etc. as well as replacement parts such as steel balls, rods, shell and head liners, scoop lips, etc.

The timber and lumber index covers the timber and lumber that is most readily available for applications such as cribbing, lagging, and supports in underground mining.

The fuel index covers refined fuel products weighted toward diesel. However, the fuel index is also considered applicable to other petroleum products.

The explosives index includes all types of blasting supplies, e.g., propellent powders, blasting caps, etc.

The tires and rubber index includes all types of tires applicable to mining operations, e.g., for LHD's, trucks, as well as other parts made of rubber such as conveyor or other belts for machinery.

The construction materials index is applicable to materials such as sand, gravel, cement, limestone, reinforcing rods, steel fasteners, etc., for use in construction of mine and mineral processing plants and related infrastructure.

The industrial materials index includes mining and mineral processing chemicals used in daily operations, e.g., wetting agents, mining reagents, dust depressants, flocculants, flotation reagents, etc.

The transportation index measures transport cost based upon an assessment of the country's normal freight transport network relevant to the mineral industry and could include, in addition to rail and truck, means such as barge and pipeline.

Table 4.--U.S. cost indexes, 1980-85

	1980	1981	1982	1983	1984[1]	1985
Mining wage............	9.19	10.06	10.82	11.27	11.56	11.90
Construction wage......	2,767.0	3,025.0	3,345.0	3,587.0	3,679.0	3,747.0
Equipment repair parts.	288.9	320.8	343.9	351.9	354.3	362.3
Bits and related steel.	305.0	333.8	339.0	343.4	354.1	355.6
Timber and lumber......	325.6	325.1	310.8	352.6	353.2	340.0
Fuel...................	674.3	805.9	761.2	684.3	669.7	633.8
Explosives.............	251.1	288.9	298.9	302.1	301.3	312.8
Tires and rubber.......	249.7	270.2	271.6	260.0	258.0	247.0
Construction materials.	287.7	310.3	330.1	352.9	355.5	358.2
Industrial materials...	274.2	304.1	312.3	315.7	319.2	323.9
Transportation.........	311.3	355.3	387.3	395.4	409.7	414.4

ESTIMATING PROCEDURE

The CES handbook is a tool to be used for mine capital and operating cost estimation and comparison. As with any tool, the skill of the user will ultimately determine the quality of the product. The evaluator must realize that the extent of thought and understanding in the input will directly affect the accuracy of the final result. When estimating the cost of an operating mine, as much information as possible should be compiled prior to cost estimation. When costing a proposed operation, it is imperative to develop a detailed mine plan before using this handbook. The method providing the maximum economic benefit given the restrictions of geometry, geology, and environment must be selected. Great care must be taken in selecting a mining method that is both applicable and practical with respect to the geometry, geology, and accessibility of the ore body, while taking into account any other parameters that might affect design. To obtain an accurate estimate, the importance of the compatibility of the stoping, mining, hauling, and general service systems with the characteristics of the deposit, as well as with each other, cannot be overemphasized.

The initial step in using this handbook is the selection of sections and individual formulas and curves within the sections to be used in the evaluation. It is presumed the estimator will have adequate knowledge of mining, mineral processing, and estimating procedures before attempting to prepare an estimate using the methods presented herein. After the data requirements have been prepared, the cost sections that apply should be studied until their contents are fully understood.

In order to effectively apply the costing system, the estimator should develop a reasonably detailed flowsheet and material balance incorporating all operations to be costed. A fairly comprehensive process flow diagram and material balance will enable the estimator to apply the system rapidly, as most of the formulas or cost curves generate costs directly as a function of capacity (usually metric tons per day). This preparatory work should be sufficiently detailed to establish the grades and recoveries for all major product streams as well as to delineate the mass flow rates (both solid and liquid) for all major product streams. Finally, any special information (required for adjustment factors) should be noted as it will enhance the accuracy of the final estimate.

Each handbook section represents a unit process in mining or mineral processing. In order to generate the costs for a desired actual or proposed operation, the estimator must first obtain the following minimum information:

The amount of ore and waste mined or concentrate produced on a daily basis.

The mining and processing method(s) employed and any peculiarities associated with the deposit.

The applicable labor rates, number of shifts operated per day, and water and electrical rates.

Once this information has been gathered, all sections required for the cost estimate should be studied to determine other information required for adjustment factors. In order to obtain the best results, the estimator should proceed through the sections in the sequence they are presented in the handbook. A more detailed discussion of the requirements for producing an acceptable cost estimate using this handbook is presented in the following section.

GUIDELINES FOR SURFACE MINING

Coverage for surface mining includes dredging, quarrying, strip mining, and open pit mining. When using this system for estimating cost data for an undeveloped deposit or for checking or verifying mining costs from a developed deposit, a minimum amount of background information must be obtained. This includes environmental, exploration, infrastructure, ore body configuration, rock competency, prevailing labor costs (including payroll burden), daily or annual tonnage, surface mining and haulage methods, and any extreme circumstances that would have an impact on the costs, such as severe weather or remoteness of the location.

A detailed explanation is included with each cost section. These explanations list the cost items used to develop the cost section, and specify exactly what is covered. Since many of the mining development, method, and haulage sections appear to overlap, each explanation must be read carefully and fully understood. Only by understanding the scope of each section can the estimator be assured that every required item will be accounted for once, and only once, in the final cost.

The following pages present some guidelines for designing surface mining systems. As with any guidelines, many exceptions exist, and many situations are not considered. In the final account, the individual evaluator's knowledge of the deposit and of the mining system will determine the accuracy of the estimate. Evaluators often assume that surface mining is preferable to underground methods. This, of course, is not always the case. For the purpose of selecting the best method and proper curves using this manual, both surface and underground techniques must be considered. The method providing the maximum economic benefit given the restrictions of geometry, geology, and environment must be selected.

Of the items that affect the economics of surface mining, the most important is stripping ratio (the amount of waste that must be removed to extract 1 mt of ore). In surface mining, overburden and waste must be removed to access the ore body. As the depth of mining increases, the rate of waste that must be removed to extract the same amount of ore also increases. A point is eventually reached where the cost of removing the ore exceeds its value. Consequently, steeply dipping narrow vein deposits must be of very high grade to justify surface mining. The method is best suited for large volume deposits occurring near the surface.

Generally, surface mining is more efficient than underground. First, more energy is required to extract and remove a ton of ore from an underground working than from a surface mine. Increases in drilling and blasting requirements per ton of ore, limits in the size of ore conveyance equipment, restrictions in haulage routes and speeds, and additional handling and rehandling of the ore all raise the total energy needs of underground mining. Increases in energy requirements escalate the production costs per ton, which in turn dictate higher cutoff grades. Second, higher ore losses are incurred in underground mining as compared to surface methods. While open pit recovery can approach 95%, underground methods such as room and pillar often leave as much as 40% of the ore behind, which translates directly into lost revenue.

In the final analysis, the decision to mine an ore body using surface methods as opposed to underground usually pivots on economics. If development, extraction, and removal costs per ton ore ore are greater for one method than the other, the least expensive technique will undoubtedly be chosen. No general optimum deposit depth exists for surface mining. The practical depth for a specific deposit is determined by the stripping ratio, ore value, working slope angle, deposit volume, extraction method, mine life, and reclamation requirements. In many instances, ore is extracted by surface methods down to an economically determined cutoff point, then underground techniques are initiated. The above guidelines are general, and since all ore bodies are shaped differently, the evaluator must decide which model most closely resembles this situation, and which method, or combination of methods, is most appropriate.

Deposit geometry is critical in the estimate of costs for both surface and underground mining. For surface methods, the total amount of waste removed per ton of ore is directly related to the shape of the deposit, and its relation to the surface topography. Surface mining techniques can be used in nearly all geologic conditions. However, factors such as weathering, fracturing, rock strength, and ground water all influence the stability of the ore and waste. Working pit slope is a function of this stability, and directly affects the production cost per ton and the economic depth of the pit.

Before deciding on a mining technique, all remaining available information should be examined. Environmental, geographical, personnel, and financial restrictions may each influence mine design. Since most sections have factors for unusual situations, this information will also increase the exactness of the cost estimation process. Although the benefits are often economically intangible, a prudent engineer must certainly study the advantages of reducing the environmental impact.

Geographical characteristics and mine location may also alter the method of extraction and haulage. In rugged areas, it may prove difficult and expensive to bring in large equipment. Mine design in extremely remote areas may be dictated by the availability of power. Mine operators often choose to forego transmission lines and haul in fuel for diesel generators, if the latter is less expensive. High-draw electrical equipment, such as conveyors, may be eliminated in favor of trucks if electric power is scarce or costly. Conversely, an abundance of electrical power will compel operators to select an electrically intensive system.

The labor force deserves careful attention during the design process. If little labor is available locally, a highly mechanized mine may prove more economically attractive than importing personnel. Unskilled local labor, if plentiful, indicates the necessity of a labor-intensive method using simpler equipment. Many labor skills are easily transferable, and should be used to advantage. In logging or farming areas, the use of heavy equipment is common, and the labor force may easily adapt to mine equipment operation.

MINING SYSTEM DESIGN

Once mining and haulage systems have been selected, they are combined with the proper development techniques and auxiliary systems to complete the mine design. Provisions must be made not only for the access, extraction, and removal of the ore, but for the physical needs of the miners and the operational needs of the equipment as well. This entails the inclusion of communication, electrical, and water systems, along with any other items required for safe extraction.

As stated earlier, the individual unit process narratives detail what the section covers and must be thoroughly understood. Before designing the mine the user must construct access roads and utilities. Development consists of clearing, preproduction stripping, and enough haul road and bench development, so that when production begins, it will continue at a uniform rate. The overall stripping ratio is the ratio of the total amount of waste to be mined to the total amount of ore. After production begins, the stripping ratio becomes the ratio of waste to ore during production, without including the amount of waste mined during development. Stripping ratio is often misleading and the user must understand what context it is used in before completing an estimate.

Several other items must be individually considered and included in the cost estimation if required. These include

1. Exploration
2. Office and Laboratories
3. Shops and warehouses
4. Engineering and construction fees
5. Administration
6. Working capital

Surface mining design and development is contingent on the value and the physical parameters of an ore body and dependent on the technologies available to mine the ore body. Table 5 shows what mining types are available in this handbook:

Table 5.--Surface mining methods

Method	Production range
Wheel loaders or diesel shovels and trucks.	1,000 - 10,000 (mtpd)
Shovels and trucks........................	8,000 - 400,000 (mtpd)
Scrapers..................................	2,000 - 250,000 (mtpd)
Crawler draglines.........................	2,000 - 15,000 (mtpd)
Walking draglines.........................	15,000 - 150,000 (mtpd)
Dredging..................................	500 - 20,000 (bank m^3/d)
Bucket wheel excavators...................	2,200 - 125,000 (mtpd)
Hydraulic mining..........................	9,500 - 58,000 (mtpd

Most of the surface development and mining sections have been developed on a capacity basis. In this case, when users generate a mine estimate based on shift designations other than what the development of the sections was based on, no adjustment is necessary. With the surface mining equipment sections, the tonnage mined by a designated amount of equipment is specified for a certain number of shifts. If the user wants to use another shift designation, an adjustment must be made. To adjust from a shift designation other than the one a curve was developed on, it is necessary to multiply the shift ratio (base/actual) times the mine capacity, and then use the adjusted value for the actual cost determination.

GUIDELINES FOR UNDERGROUND MINING

The underground mining includes individual development sections for drifting, raising, shaft sinking, stope development, various mining methods, underground mine haulage, general plant, and underground mine administrative cost. When using this system for estimating cost data for an undeveloped deposit or for checking or verifying mining costs from a developed deposit, a minimum amount of background information must be obtained. This includes environmental, exploration, infrastructure, ore body depth, rock type and hardness, support or ground conditions, prevailing labor costs (including payroll burden), daily or annual tonnage, underground mining and haulage methods, and any extreme circumstances that would have an impact on the costs, such as severe weather or remoteness of the location.

A detailed explanation is included with each cost section. These explanations list the cost items used to develop the cost section and specify exactly what is covered. Since many of the mining development, method, and haulage sections appear to overlap, each explanation must be read carefully and fully understood. Only by understanding the scope of each section can the estimator be assured that every required item will be accounted for once, and only once, in the final cost.

The following pages present some guidelines for designing mining systems. As with any guidelines, many exceptions exist, and many situations are not considered. In the final account, the individual evaluator's knowledge of the deposit, and of the mining system he has designed, will determine the accuracy of the estimate.

Geometry

Initially, the geometry of the deposit must be understood to develop a mine plan. An actual or estimated length, width, thickness, strike, dip, continuity, shape, and relation to surface topography are all required. Once these are established, the list given in table 6. will provide a starting point in determining a mining method.

Table 6.--Guidelines for selection of mining method

Deposit	Method
All deposits, near surface[1]	Surface mining.
Bedded deposits, at depth, dip less than 30°	Room and Pillar, continuous mining, block caving.
Narrow vein deposits, at depth[2]	Sublevel-longhole, shrinkage stoping, vertical crater retreat, cut and fill, resuing.
Small, irregular deposits, at depth	Square set, cut and fill, resuing.
Wide vein deposits, at depth[3]	Sublevel-longhole, vertical crater retreat, cut and fill.
Massive deposits, at depth	Block caving.

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[1] For estimating purposes, near surface can be taken to mean a depth less than 150 m; however, the depth of economically feasible mining will vary greatly.

[2] Limits for stope width are stated in each individual stope preparation curve explanation.

[3] It must be remembered that for wide vein deposits, stopes can run perpendicular to the strike, although some ore may be lost to pillars.

Geology

Next, the geology of the ore and wall rock must be examined. Ore and wall rock characteristics directly affect method selection and subsequent mining costs. The extra time and supplies required to keep stopes and haulage ways open will obviously increase the total cost per metric ton of ore significantly.

Economics

The economics of the various methods must of course be considered. Once the geometry and geology of the deposit have been established, the choices of mining method are narrowed significantly. At this point, if no other factors prohibit the choice, the least expensive remaining alternative is selected. Once it becomes necessary to use underground methods, the evaluator must remember that, for comparison purposes, stope preparation costs add to the relative cost per ton of ore extracted.

Other Parameters

Before deciding on a mining technique, all remaining available information should be examined. Environmental, geographical, personnel, and financial restrictions may each influence mine design. Since most sections have factors for unusual situations, this information will also increase the exactness of the cost estimation process.

Although the benefits are often economically intangible, a prudent engineer must certainly study the advantages of reducing the environmental impact. Serious environmental problems associated with mining include aesthetics, noise, dust, acidic mine water, and subsidence. Underground mining will substantially reduce the first three of these problems. For this reason, underground methods must be considered in environmentally sensitive areas, even if surface mining appears less expensive. Where subsidence is a problem, backfilling or permanent support will be required even though the deposit may lend itself to less expensive techniques.

Geographical characteristics and mine location may also alter the method of extraction and haulage. In rugged areas, it may prove difficult and expensive to bring in large equipment. In this case, the most economically effective alternatives include labor-intensive methods such as cut & fill or shrinkage stoping. Mine design in extremely remote areas may be dictated by the availability of power. Mine operators often choose to forego transmission lines and haul in fuel for diesel generators, if the latter is less expensive. High-draw electrical equipment, such as conveyors and hoists, may be eliminated in favor of trucks if electric power is scarce or costly. Conversely, an abundance of electrical power will compel operators to select an electrically intensive system.

The labor force deserves careful attention during the design process. If little labor is available locally, a highly mechanized mine may prove more economically attractive than importing personnel. Unskilled local labor, if plentiful, indicates the necessity of a labor-intensive method using simpler equipment, such as jacklegs and slushers. Many labor skills are easily transferable, and should be used to advantage. In logging or farming areas, the use of heavy equipment is common, and the labor force may easily adapt to mine equipment operation.

Many mining methods described in the manual require high initial capital investments, even though production costs may be quite low. Block caving, for example, requires a large amount of time and money for preproduction development, and receipt of initial revenues are subject to an extensive lag time. Similar situations occur with sublevel and shrinkage stoping, although not to the same extent. Some methods, such as hard rock room & pillar, have relatively low initial costs, and since ore is mined immediately, revenues are realized early in the life of the operation. Capital availability may also affect the selection of haulage methods. Not only must the respective advantages of rail, conveyor, truck, load-haul-dump (LHD), or hoist haulage be compared on a deposit accessibility basis, they must also be compared on a production cost basis, and, just as important if capital is short, an initial cost basis.

Mining System Design

Once mining and haulage systems have been selected, they are combined with the proper development techniques and auxiliary systems to complete the mine design. Provisions must be made not only for the access, extraction, removal, and storage of the ore, but for the physical needs of the miners and the operational needs of the equipment as well. This entails the inclusion of communication, ventilation, electrical, and water systems, along with any other items required for safe extraction.

As stated earlier, the individual unit process narratives detail what the section covers and must be thoroughly understood. For instance, since each mine has unique ventilation requirements, the ventilation section contains no allowance for separate ventilation shafts. If one is needed, either the raise boring, raise, or shaft sinking sections must be utilized to account for its construction cost.

Consider the problem of first developing, then mining a vein deposit using a vertical crater retreat method shown in figure 1. First, all mining levels of the ore body have to be accessed. To accomplish this, a combination of shafts and drifts, ramps and drifts, or drifts and raises are designed to connect the surface with the ore body. During preproduction development, enough levels and stopes must be opened to allow for uninterrupted production once mining begins. Eventually, drifts on each level will be of sufficient length to access all planned stopes. Crosscuts from these drifts to the stopes, and all development within the stopes, are covered in the stope preparation sections. Consequently, the only design requirements for the evaluator are the number of stopes needed for initial production, their locations, and their dimensions. The vertical dimension of these stopes will determine the level interval.

Next, a transportation system must be developed capable of delivering ore from the stopes to the mineral processing facility. In this case, it is assumed that all ore will be moved out of the stope to an ore pass using LHD's. The cost of these units will be accounted for using the LHD portion of the mine equipment section. Ore will be delivered to the bottom level through the ore pass, where it will be hoisted to the surface by way of a combination haulage-access shaft. The ore pass will be raised, or raised bored, from a point near the shaft on the lowest level to the uppermost level. Either short drifts or feeder raises connect this ore pass to a point central to the stopes on each level. Regardless of the choice of ore pass feed method, costs must be calculated for both the ore pass and the connections. The design requires the excavation of an ore pocket at the bottom of the ore pass. It should be capable of handling surges in production or breakdowns of the hoist. Hoisting facilities will also be required to lift the ore out of the mine. From the top of the haulage shaft, ore will be taken to the mill by conveyor. The cost of this conveyor should be attributed to the mine.

Several systems are needed to provide services for workers and equipment. First, fresh air is a necessity for the workers. In this case, air will pass down a separate ventilation shaft, through the stopes and access drifts, and out the haulage shaft. Although the ventilation section covers costs of fans and all auxiliary equipment, the expense of the separate ventilation shaft should be calculated using the raise, raise boring, or shaft sinking sections, depending on construction method. A drainage and disposal system will be needed in any mine using or producing water, and a communication system is required in all mines for worker safety. Equipment needs are primarily met by an underground shop or shops for maintenance. The number and size of shops depends upon the type and amount of equipment, and the underground mobility between levels. Equipment demands also include water, compressed air, fuel, and electricity. Although water and electricity will be needed in all cases, fueling and compressed air systems may not be necessary. If the respective equipment is not incorporated in the mining technique, these systems should be eliminated. In this example, compressed air is needed for down-the-hole drills, and fuel is required for LHD's.

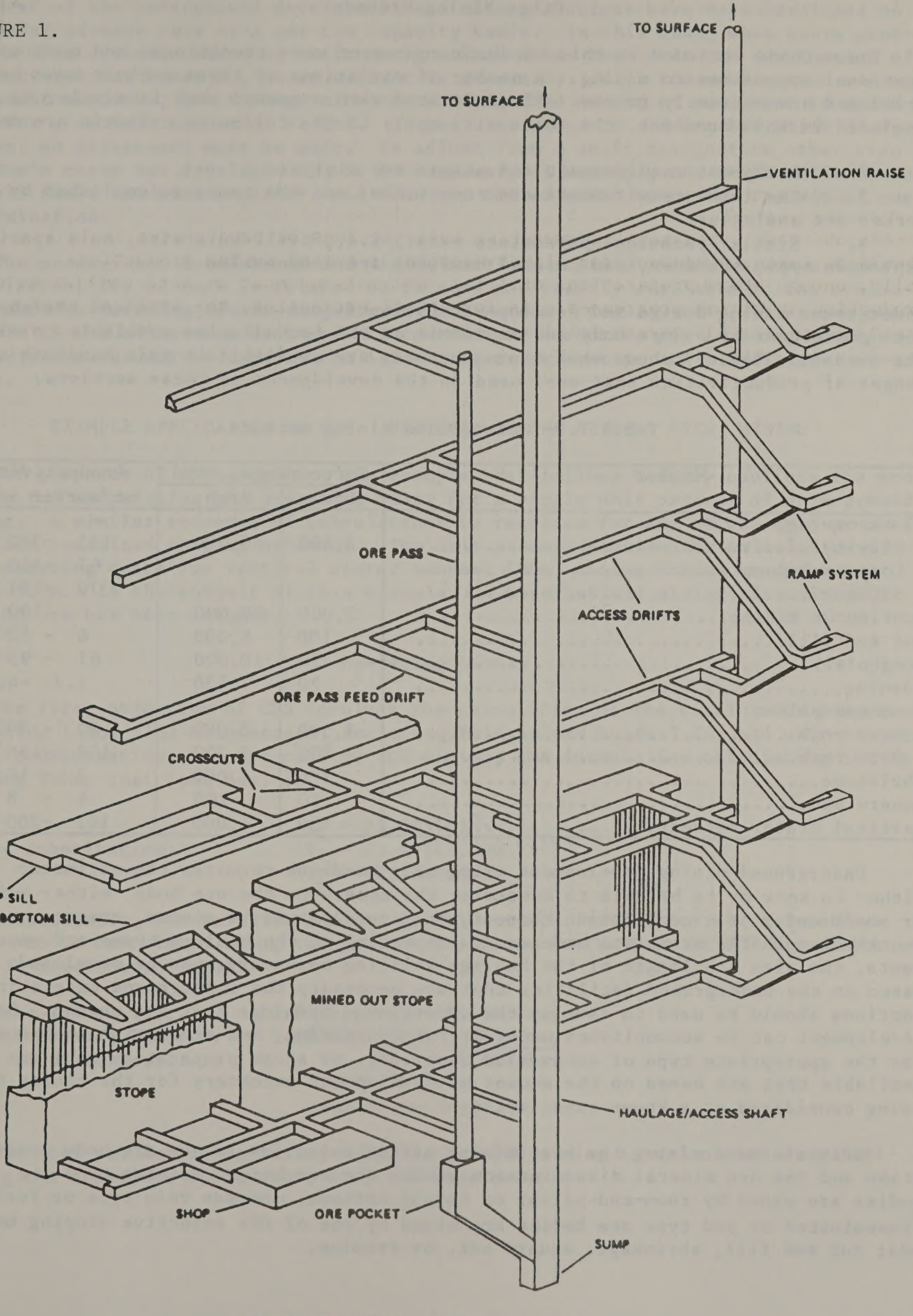
At this point, all capital costs attributed directly to underground mine development have been considered. To estimate operating costs associated with extracting the ore, it is imperative that selected mining and haulage techniques be understood, and that corresponding operating cost sections be used correctly. Care should be taken to account for all development required during production. Specifically, enough stope preparation, drifting, and raising must be performed to maintain production as mining progresses. As for actual extraction, the vertical crater retreat mining section covers drilling, blasting, and handling the ore in the stope. In addition, this section accounts for a 200-m haul of the ore using LHD's. If carefully designed, this 200-m haul will cover the distance from the stope to the ore pass feeder. The mining section also covers any miscellaneous items and auxiliary ventilation needed in the stope. After the ore is fed to the ore pass with the LHD's, it falls to the ore pocket, where it is eventually loaded onto a skip. The hoisting section is used to account for the cost of lifting the ore up the shaft. At the top of the shaft, the ore spills into a bin which, in turn, feeds directly onto the mine-to-mill conveyor. Operating costs for the conveyor are also included in the total mine operating cost.

With the exception of fueling systems, which are usually gravity fed, all other underground systems will have daily operating costs. Sections for ventilation, compressed air, drainage and disposal, water supply, electrical, and communication systems will all be utilized, along with general items. If any core drilling is required to maintain reserves, a cost for this is also essential.

The previous example addresses only the design and cost problems directly associated with extraction. Several other items must be individually considered and included in the cost estimation if required. These include

1. Clearing
2. Access roads
3. Exploration
4. Office and laboratories
5. Shops and warehouses
6. Surface buildings
7. Engineering and construction fees
8. Administration
9. Working capital

FIGURE 1.



GENERALIZED VERTICAL CRATER RETREAT MINE

Other Mining Methods

The methods included in this handbook represent many traditional and most conventional approaches to mining. A number of variations of these methods have been tried and are currently in use. If confronted with a method that is similar to one included in this handbook, the costs will apply if the following criteria are met:

1. Equipment requirements and usages are similar.
2. The labor requirements are comparable, and the tasks accomplished by each worker are analogous.
3. Similar technical parameters exist, i.e., drill-hole size, hole spacing, explosive type, ore draw, and initial handling are comparable.

Underground mining design and development is contingent on the value and the physical parameters of an ore body and dependent on the technologies available to mine the orebody. Table 7 shows what mining methods are available in this handbook and ranges of productivities that were used in the development of these sections.

Table 7. - Underground mining methods

Method	Curve range, mtpd		Productivity
	Low	High	mt/worker shift
Block caving:			
Gravity	2,500	40,000	115 -302
Load-haul-dump			67 -160
Slusher			70 -181
Continuous mining	2,000	30,000	100
Cut and fill	100	8,000	6 - 12
Longhole	350	10,000	61 - 95
Resuing	20	450	1.7 -4.2
Room-and-pillar:			
Hard rock	1,500	8,000	82 - 99
Soft rock	800	9,500	102 -136
Shrinkage	100	4,000	3 - 10
Square set	20	200	4 - 8
Vertical crater retreat	650	4,000	107 -200

Underground mining development using this handbook requires the estimator either to know or to be able to determine the access to the ore body, either adit or shaft entry or a combination thereof, and any alternative access, service, or ventilation shafts or raises necessary. Depending on the haulage types and requirements, the size and length of the haulage drifting necessary, can be developed. Based on the underground facilities that are necessary the underground excavation sections should be used to develop the underground openings that are needed. Stope development can be accomplished using drifting, raising, and excavation sections for the appropriate type of excavation necessary, or stope preparation sections are available that are based on the amount of development necessary for the mining type being considered at a known capacity.

Criteria determining the best mining method selection is the ore body configuration and the ore mineral dissemination within the ore body. Massive type ore bodies are mined by room-and-pillar or caving methods, whereas vein type or further disseminated or pod type ore bodies are mined by one of the selective stoping methods; cut and fill, shrinkage, square set, or resuing.

Most of the underground development and mining sections have been developed on a per meter advance rate or a per ton capacity basis. In this case, when users generate a mine estimate based on shift designations other than what the development of the sections was based on, no adjustment is necessary. With the underground mining equipment sections, the tonnage mined by a designated amount of equipment is specified for a certain number of shifts. If the user wants to use another shift designation, an adjustment must be made. To adjust from a shift designation other than the one a curve was developed on, it is necessary to multiply the shift ratio (base/actual) times the mine capacity, and then use the adjusted value for the actual cost determination.

The underground development and mining sections contain a rock hardness factor but blastability of rock is related to factors not readily available to the evaluator, such as jointing, fracture patterns, and burden. Consequently, it is not considered in the adjustment factors. If contract or incentive pay is being considered, adjustments must be made to the labor cost to account for this additional expense.

EXAMPLE APPLICATION OF CES: VERTICAL CRATER RETREAT (VCR) MINING

For purposes of illustration, the example that follows briefly outlines the procedure for calculating the operating costs for a single unit process of underground mining. A similar sequence of calculations is required for any of the unit process sections contained in this handbook. The unit process section for calculation of the operating costs for vertical crater retreat (VCR) mining (refer to section 5.2.1.9.10.) is the subject of this example. A hypothetical mining rate of 2,000 mtpd of ore has been assumed.

Operating Labor

The first objective of CES involves the calculation of the total labor (direct operating labor plus maintenance, including fringes and burden) for the unit process under consideration. In the case of VCR mining, the formula for calculating the operating labor cost (per day) is

$$Y_L = 23.075(X)^{0.595}$$

By substitution: $Y_L = 23.075(2,000)^{0.595}$

$$Y_L = \$2,124/\text{day}.$$

Subsequently, the relative amounts for direct operating labor and maintenance labor can be calculated using the percentages given in the text of 87% mine labor and 13% maintenance labor.

Mine labor..........	(0.87)(2,124) =	$1,848/day
Maintenance labor...	(0.13)(2,124) =	276/day
Total labor.......		2,124/day

Operating Supplies

The cost per day of operating supplies for VCR mining is calculated by substituting the capacity, 2,000 mtpd, into the equation

$$Y_S = 2.152(X)^{0.947}$$
$$Y_S = 2.152(2{,}000)^{0.947}$$
$$Y_S = \$2{,}877/\text{day}.$$

The costs of the components of the operating supplies cost can then be calculated using the percentages given in the text.

Blasting supplies..................	(0.69)(2,877) =	$1,985/day
Drill bits and steel..............	(0.13)(2,877) =	374/day
Miscellaneous items................	(0.09)(2,877) =	259/day
Material waste.....................	(0.09)(2,877) =	259/day
Total operating supply cost......		2,877/day

Equipment Operation

The cost per day of equipment operation for VCR mining is calculated by substituting the capacity, 2,000 mtpd, into the equation

$$Y_E = 1.502(X)^{0.792}$$
$$Y_E = 1.502(2{,}000)^{0.792}$$
$$Y_E = \$618/\text{day}$$

The costs of the components of the equipment operation cost can then be calculated using the percentages given in the text.

Maintenance and overhaul parts.......	(0.44)(618) =	$272/day
Fuel.................................	(0.33)(618) =	204/day
Tires................................	(0.16)(618) =	99/day
Lubrication..........................	(0.07)(618) =	43/day
Total Equipment Operating Cost.....		618/day

Adjustment Factors

Rock Hardness Factor

Provision is made for compressive strength of rock varying from the 31,700 psi used to develop the base case costs. To illustrate the application of the rock hardness adjustment factor it is assumed that the compressive strength of the rock considered in the previous example is 70,000 psi. The compressive strength is substituted for the independent variable, C, in pounds per square inch, in the factor equations for labor, supply, and equipment operation.

Labor factor $(F_L) = (0.388)(C)^{0.093}$
$(F_L) = (0.388)(70{,}000)^{0.093} = 1.10$

Supply factor $(F_S) = (0.579)(C)^{0.054}$
$(F_S) = (0.579)(70{,}000)^{0.054} = 1.06$

Equipment operation factor $(F_E) = (0.716)(C)^{0.033}$
$(F_E) = (0.716)(70{,}000)^{0.033} = 1.03$

Backfilled Stope Factor

It is further assumed that backfilling of stopes is applicable to this hypothetical operation. To adjust the costs for this variation, the backfilled stope factor is employed. In this case, the independent variable, X, represents metric tons per day of ore.

Labor factor $(F_L) = (0.863)(X)(2{,}000)^{0.030} = 1.08$

Supply factor $(F_S) = (1.635)(X)(2{,}000)^{0.027} = 2.01$

Total Adjusted Costs

Finally, the adjustment factors must be applied to the appropriate costs as derived from the base case cost formulas.

Total labor cost ($2,124/day)(1.10)(1.08) = $2,523/day

Total supply cost ($2,877/day)(1.06)(2.01) = $6,130/day

Total equipment operating cost ($618/day)(1.03) = $637/day

The application of other adjustment factors, and all other adjustment factors presented in the various mining sections, is essentially the same as shown in the examples above.

Summation of Costs

Finally, the estimator should sum the capital and operating costs. Significant figures should be taken into account at this time if the estimator has not already done so. The cost equations given in the text have not been reduced to significant figures, as they are the product of a statistical analysis. It is recommended that the estimator express no more than three significant figures (depending on the precision of the input data).

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Worthington Pump Co.

1.1. ENVIRONMENTAL--CAPITAL COSTS

1.1.1. ENVIRONMENTAL ASSESSMENTS AND ENVIRONMENTAL IMPACT STATEMENTS

Background information, guidelines, and generalized costs are presented in this section to assist in estimating costs for environmental studies. Time required to collect baseline data averages 1 to 3 years; however, as much as 5 years may be needed to finalize an environmental impact statement (EIS) for an environmentally sensitive area.

BACKGROUND INFORMATION

Environmental laws and regulations pertaining to the mining industry are continually being revised at the Federal, State, county, and municipal levels. To conform with existing environmental regulations, mining and milling operations must apply for permits at various stages of development (i.e., exploration, construction, operation, and reclamation). In most cases, before permit applications, baseline information about the environment prior to commencement of mining and/or milling activity must be gathered. This study, usually prepared by an environmental con- sulting firm, is paid for by the mining-milling company and then presented to ap- propriate government agencies for an assessment of the impact of the mining-milling activity. If formal reports are required, i.e., an environmental assessment (EA) and/or an EIS, the mining-milling company must pay the majority of the cost for these studies also.

Multiple environmental studies may be required for various stages of a mine-mill development and operation (i.e., exploration access, mine development, etc.). Multiple studies are typical if a company has not made an economic feasibility decision on the mineral deposit. Conversely, a single environmental study may be sufficient for mining-milling from a specific area by more than one company (i.e., phosphate deposits in southern Idaho, coal seams in western Montana).

GUIDELINES

All developing or expanding mining-milling operations will sustain environmental study related costs. Ownership of land affected by a mining-milling operation (including utility lines, access roads, surface facilities, waste dumps, etc.) is the primary key in determining the amount of environmental studies required to satisfy environmental laws and regulations. Cost of an environmental study is directly related to the complexity and variations associated with types of investigations necessary (see the following tabulation for study types and typical costs).

Because of site-specific variations in each investigation, the cost range for environmental studies deviates immensely. The following guidelines will help the estimator determine environmental study costs:

1. For an operation less than 100 mtpd, completely on private land without anticipated impacts to adjacent lands, cost for an environmental summary suf- ficient for permit applications would be $25,000 to $50,000.

2. For an operation less than 100 mtpd, completely on private land with anticipated impacts to adjacent lands, use the base cost of $25,000 to $50,000 and add the cost of the appropriate baseline study element from the following tabulation (i.e.,

if ground water would be impacted, add the cost from the range for a ground water study).

3. Use the cost from the following tabulation for a final EA for all operations over 100 mtpd with an anticipated insignificant impact to the environment, regardless of site ownership. Use proportionately higher costs for higher tonnages in each cost range.

4. For operations on private, State, municipal, and/or Federal land with an anticipated moderate environmental impact, use the appropriate cost from the following tabulation for a final EIS.

5. For operations on private, State, municipal, and/or Federal land with an anticipated significant impact to the environment, the cost for environmental studies is typically 5 times and may be up to 10 times the cost shown in the following tabulation for a final EIS. (For example, a 1,000-mtpd underground mine and adjacent mill planning to significantly alter the local hydrology, could face environmental study costs of $3.0 million. Environmental study costs for a 1,500-mtpd surface mine adjacent to a wilderness area may be in the range of $6.5 million).

Typical cost ranges for environmental studies, thousand dollars

Baseline study elements	Underground		Surface		Cost modifying factors
	+2,000 mtpd	-2,000 mtpd	+2,000 mtpd	-2,000 mtpd	
Surface water...	10- 35	20- 70	10- 70	50- 175	Hydrology (i.e., number of streams), 3-25 sites per operation, site sampled 3-7 times per year, $1,000 per analysis.
Ground water....	30- 80	60-135	30-160	100- 250	Hydrology, availability of subsurface sample sites.
Air quality.....	10- 60	30-100	50-150	100- 325	Geography, proximity of meteorologic station.
Geology.........	2- 20	10- 50	2- 20	0- 50	Access to mining company data.
Soil............	5- 20	15- 40	10- 60	40- 90	Existence of potential problems during operation (i.e., slope stability), surface area.
Vegetation......	5- 15	10- 40	5- 20	15- 60	Surface area, endangered species.
Wildlife........	8- 15	10- 40	8- 20	15- 60	Do.
Visual..........	2- 5	3- 20	2- 10	5- 60	Proximity to cities, national parks, scenic areas, wilderness areas, etc.
Archeological...	1- 5	2- 15	1- 5	2- 20	If known archeological sites exist, costs increase substantially.
Socioeconomic...	4- 12	5- 25	4- 12	5- 25	Demographic characteristics.
Compile baseline data.	6- 12	10- 20	6- 20	10- 150	None.
Final EA......	85-280	175-550	130-550	350-1,265	Do.
Compile EIS.....	15- 30	20- 70	15-100	70- 300	Do.
Final EIS...	100-310	195-625	145-650	425-1,565	Do.

EA Envrionmental assessment.
EIS Environmental impact statement.

2.1. SURFACE MINING--CAPITAL COSTS

2.1.1. EXPLORATION

Exploration costs and data were partly derived from mining and exploration companies and contractors. However, credit is given to Mr. William Salisbury of Salisbury and Dietz, Spokane, WA, for his generous supply of data and overall review.

Exploration can be defined as all the activities and evaluations performed in order to locate and define mineral deposits for the purpose of extraction now or in the future.

Exploration covers a wide range of activities from that of a prospector searching for mineral outcrops to the sophisticated equipment in ground or airborne surveys attempting to detect hidden mineral deposits, followed by extensive sampling and logging of excavations or drilling programs.

An organized exploration program consists of the four following principal stages:

Stage 1. Regional Appraisal
Stage 2. Detailed Reconnaissance of Favorable Areas
Stage 3. Detailed Surface Appraisal of Target Areas
Stage 4. Detailed Three-Dimensional Sampling and Preliminary Evaluation

Costs in this section are directed to those related to exploration activity at the level of "project" status. The point where a company's general exploration program is elevated to "project" status will differ from company to company (or project), but in general this transition is marked by such activity as land purchase or lease, claim staking, geophysical and geological surveys, drilling, etc. In any case, exploration expenditures and efforts increase dramatically over a small unit area. Labor costs are the major cost component and drilling is most often the principal cost item for a project. Exploration costs will range widely depending on methods used, size of project, commodity sought, remoteness, terrain and vegetation conditions, weather, geologic complexity, etc.

Detailed Surface Appraisal of Target Areas

If the results of the detailed reconnaissance are favorable, they may indicate areas ranging in size from 3 to 130 km^2 where more detailed in- vestigation is warranted. This stage of investigation would include all of the ground survey techniques or methods which were used in stage 2, but with more refinement, closer intervals, and greater detail. The methods or techniques used might include additional outcrop examination, geologic mapping, boulder tracking, rock and specialized sampling, and possibly assaying. In addition, the various ground geophysical studies including gravity, magnetic, radiometric, seismic, resistivity, self-potential, and induced polarization would be made. Possibly, this stage would also warrant some trench excavation and drilling, plus field and laboratory tests. Unit costs for the various techniques or methods are given in the exploration tabulation.

Detailed Three-Dimensional Sampling and Preliminary Evaluation

A detailed three-dimensional survey or sampling of a target area ranging in size from 1 to 25 km^2 or more would be made if it appeared that an economical ore body existed. The sampling or survey would be made to determine boundaries or limits and depth, size, shape, mineralization, and grade. This stage of exploration would probably include an extensive drilling program together with borehole logging and geologic mapping. Excavation of test trenches, shafts, and adits might also be included. Samples would be taken, field and laboratory tests would be conducted, and assays would be made to permit econ- omic evaluations to be made. The cost of the stage 4 exploration could vary greatly depending on location, accessibility, ground cover, type of deposit, and the extent of a drilling or excavation program. Unit costs for various techniques or methods are given in the following tabulation.

Exploration

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geological Methods:				
Surface geological mapping.............	2 to 4 men	3 to 12/km^2	\$75 to \$275/km^2	Rate of production and cost depend on terrain, ground cover, complexity of geology, detail required, and scale of mapping.
Geological inference..			\$275 to \$760/d	A qualified geologist interpret data shown on maps, photographs, or field investigations.
Geophysical Methods:				
Gravitational survey..	1 geophysicist 2- to 3-man survey crew	12 to 50/ profile km	\$380 to \$1100/ profile km	Production varies from a few to 50 readings per day depending on type of equipment. Production also depends on station spacing and terrain. Surveying is the costly phase of method.
Magnetic Survey:				
Airborne...........	1 to 3 men		\$50 to \$90/line km plus \$2 to \$16/line km for interpretation	High sensitivity, helicopter, magnetic, electromagnetic, radioactivity surveys, etc., are usually taken concurrently from aircraft at 400 to 800 line km/d. Production and cost depend on type of aircraft equipment, etc.
Ground.............	2 to 3 men	4 to 6/ profile km	\$160 to \$180/ line km \$2.60 to \$2.90/ grid point	Production depends on precision, spacing, of readings and type of readings, type of equipment, weather, terrain, and mode of travel.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Seismic survey:				
0- 150-m depth........	2 to 7 men	1 to 4/depth determination	$35 to $110/depth determination	Portable equipment with 5 to 15 determinations per day.
150-m depth...........	15 to 20 men	5 to 10/depth determination	$180 to $270/depth determination	Vibroseis equipment with 3 to 15 depth determinations per day.
Very low frequency......	2 men		$315 to $385/line km.	Includes about $40/line km for interpretation.
Resistivity Survey......	1 geophysicist 1 to 4 asst.	2 to 3/depth determination	$57 to $114/depth determination	None.
Electromagnetic Survey:				
Airborne.............				Usually taken concurrently with magnetic and radioactivity surveys from 1 aircraft at 400 line km or 80 km^2/d.
Ground...............	1 to 4 men	1 to 6/line km	$163 to $390/ line km	Readings taken at 25- 50-m intervals covering 5 to 10 km/d; dependent on on type of equipment, terrain, and mode of travel.
EMP..................	3 men		$4000/loop $1290/line km $2900/km^2	Parameters: Approximately 60-m by 120-m grid spacing; 430-m by 850-m loop; 10 lines, 15 stations/line; 10.3 km^2 costs include interpretation.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geochemical methods:				
Stream sediment sampling............	1 man		$19 to $38/km^2	Depends on sampling interval terrain, access, and mode of travel.
Reconnaissance soil sampling............	1 man	0.05 to 0.20/ sample	$11 to $24/sample	50 to 200 samples/d depending on access, terrain, ground cover, and geologic complexity.
Humus sampling......			$28 to $55/sample	None.
Biological sampling.			$28 to $55/sample	Do.
Water samples.......			$50 to $95/sample	Do.
Test pit:				
Trenching............				Depends on whether hand or equipment excavated.
Earth................	1 to 3 men	0.1 to 2.0/m^3		$2 to $55/m^3
Do.				
Rock..................	3 men	0.2 to 3.5/m^3		$11 to $100/m^3
Do.				

Helicopter cost and comparison

Manufacturer and model	Approx cost/h[1]	Passenger capacity[2]	Effective payload (h.o.g.e.[3]), kg		Cruise	
			Sea level	2700m	Speed, mph	Range, km
Hiller-Soloy 12-J...	$ 300	2	450	360	145	240
Bell-Soloy 47G3.....	305	2	500	360	145	350
Bell 206B...........	380	4	450	320	195	550
Hughes 500C.........	360	4	570	360	240	560
Hughes 500D.........	410	4	610	550	255	480
SUD Allouette Lama..	575	4	1,000	900	175	480
Bell 205............	1,040	14[4]	2,100	1,100	195	210
Bell 214............	1,855	15[4]	3,600	2,500	280	560

[1] Charter rate, includes fuel.

[2] Without pilot.

[3] Hovering out of ground effect.

[4] Varies, maximum capacity given.

Source: Modified and updated from William G. Salisbury.

Analytic costs

	Assay	Geochemical		Assay	Geochemical
Aluminum..........	$8.74	NAp	Lead..............	$4.96	$2.15
Antimony..........	8.98	$4.12	Lithium...........	7.42	NAp
Arsenic...........	10.36	4.32	Magnesium.........	9.11	3.30
Barium............	10.12	4.78	Manganese.........	6.60	3.12
Beryllium.........	12.10	NAp	Mercury...........	9.75	4.22
Bismuth...........	7.59	3.50	Molybdenum........	5.98	2.43
Cadmium...........	5.04	2.46	Nickel............	4.96	2.15
Chromium..........	7.75	4.28	Platinum..........	27.72	NAp
Cobalt............	5.46	2.15	Potassium.........	8.41	NAp
Copper............	4.96	2.15	Silica............	10.36	NAp
Copper oxide......	4.29	NAp	Silver............	8.45	2.81
Fluorine..........	NAp	5.73	Tungsten..........	11.02	5.72
Gold and silver...	9.07	NAp	Zinc..............	4.55	2.15
Iron..............	5.94	2.90			

NAp Not applicable.

NOTE.--Sample preparation costs are assay--$1.85 and geochemical--$1.15. Semi-quantitative spectrographic analysis for 30 to 40 elements is $23.32.

Drill capacities (maximum, under ideal conditions)

Drill Model	- HOLE LENGTH, METERS (feet) -					Approx av weight lb (kg)
	EW	AW	BW	NW (Nc)	HW	
Truck mounted -hauled:						
Joy 22...........	NAp	NAp	900 (3000)	600 (2000)	NAp	4000 (1800)
Longyear 24......	270 (890)	220 (720)	NAp	NAp	NAp	1075 (490)
Longyear 34......	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	200 (700)[1]	3300 (1500)
Longyear 38......	NAp	940 (3100)[1]	700 (2400)[1]	580 (1900)[1]	370 (1200)[1]	3300 (1500)
Longyear 44......	NAp	1500 (5000)[1]	1200 (3940)[1]	936 (3070)[1]	716 (2350)[1]	5100 (2300)
Diamond Drill DDC	NAp	550 (1800)	500 (1650)	300 (1000)	NAp	1900 (860)
CP 670 Rotary....	NAp	NAp	NAp	NAp	+300[2] (+1000)[2]	
Helicopter transportable:						
Hydraulic Winkie..	NAp	300[3] (1000)[3]	240[4] (800)[4]	44-30[5] (100)[5]	NAp	550 (250)
Diameck 251.......	NAp	370 (1200)	NAp	NAp	NAp	2500 (1100)
Acker Mark III....	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	NAp	2600 (1200)
Acker Mark II.....	NAp	550 (1800)	495 (1625)	380 (1250)	340 (1100)	2860 (1300)
Ingersol Rand T4W.	NAp	NAp	NAp	NAp	760[2] (2500)[2]	

NAp Not applicable.

[1] Q Series wire line.

[2] Rated capacity.

[3] IEX.

[4] IAX.

[5] BW.

NOTE: Figures are maximum capacities under ideal conditions.

Source: Data from William G. Salisbury, Salisbury & Dietz Inc., as collected from literature and as provided by contractors, May 1980.

DRILLING

CORE DRILLING

Core drilling varies from nonexistent to extensive, depending on many unknown factors. Core drilling is performed on centers varying from 30- to 245 m and to varying depths. The following tabulation gives the average range of costs for core diameter and depth of hole for drilling medium hard rocks. Costs could be higher or lower depending on hardness, location, access, and weather conditions.

Drilling cost, dollars per meter

Core		Drilling depth range, m			
Size	Diam, cm	0-150	150-300	300-450	450-600
PQ.......	8.49	\$100-\$115	\$125-\$138	NAp	NAp
NC[1]......	6.10	62- 79	69- 85	\$90	\$100
NX[1]......	5.40	59- 71	62- 75	80	90
BX.......	4.13	49- 64	52- 69	75	85
AX.......	2.86	43- 57	49- 62	70	80
EX.......	2.22	36- 52	43- 59	NAp	NAp

NAp Not applicable.

[1] Primarily surface exploration core sizes.

Subcontractor Factor If drilling is accomplished by a drilling subcontractor, multiply cost by 1.10 to compensate for subcontractor's markup.

ROTARY DRILLING

Conventional...................	\$125-\$185/h; \$7-\$36/m.
Reverse circulation...........	\$125-\$185/h; \$11-\$39/m.
Mobilization-demobilization...	\$1,500-\$2,500 and \$1.90-\$2.20/km.

PERCUSSION DRILLING

Downhole hammer...............	\$40-\$59/m.
Mobilization-demobilization...	\$1,500-\$2,500 and \$1.90-\$2.20/km.

CAUTION: Drilling costs are impacted significantly by demand. Costs correlate poorly with industrial inflation factors. Base costs here are representative of January 1984 costs, a time of low drilling demand and very depressed prices for drilling contractors.

Contract downhole logging costs--survey changes

	Cost per--			Plus cost
	Day	Week	Month	per meter
Portable gamma ray rental	NAp	NAp	[1]$2,600	NAp
Truck gamma ray surface profile resistivity:				
Daily	$420	NAp	NAp	$0.69
Weekly	NAp	$1,588	NAp	0.36
Monthly	NAp	NAp	4,646	0.36
Directional survey	NAp	NAp	735	0.15

[1] Month minimum.

Loss of equipment charge--Contractee is charged for replacement value of equipment lost. Probes may cost $3,200 and cable may cost $2.30/m.

Mobilization-demobilization charge - $50/d/person; $0.90/mile over 100 mile/d mobilization.

GAS--MILEAGE:

Assume on average, 80 mi/d for 18 days going to field project.
Total miles = 1,440 miles.
Assume 300 miles are driven each way going to and from project.
Total miles = 600 miles.

1,440 miles + 600 miles = 2,040 miles
(2,040)($0.10/mi) = $204/month

Assume: 20 working d/month, 10 days off/month (8 days rest and 2 days off, holiday, weather, project supervisor discussions).

LABOR:

	Annual salary equivalent (overhead)	Sampling program work schedule
Supervisor	$36,000 (35%)	4 d/month (includes travel, supervisory, and interpretation.)
Full-time geologist	26,000 (35%)	Full-time (20 d/month).
Part-time sampler	18,000 (15%)	Full-time (20 d/month).

	Annual cost plus salary overhead	Per month	$/sampling project month
1 supervisor	$48,600	$4,050	$ 810
1 full-time geologist	35,100	2,925	2,925
1 part-time sampler	20,700	1,725	1,725
Pay total for month			$5,460

TRAVEL:

A. Per diem:

	Per diem rate	Days on per diem	Total per diem
Supervisor..........	$50	2.75	$ 137.50
Full-time geologist.	50	19.0	950.00
Part-time sampler...	50	19.0	950.00
			2,037.50
Per diem total for month.			2,038.00

B. Vehicle Cost:

Assume on average 300 miles to project area and 80 miles driven to and from point of lodging.

1. Geologist and Sampler

Vehicle is 4 x 4 Ford Bronco, lease rate is $1,200 month, mileage free. Assume vehicle uses unleaded gas costing $1.10/gal at a rate averaging 12 mi/gal.

$1.10/12 = 9.2¢/mi + 0.8¢/mi oil and lube = 10¢/mi

a. Gas cost

1. Miles to and from project area:
300 mi/trip x 2 trips/work period x 2 trips/month
= 1,200 mi/month.

2. Miles to and from field lodging to project:
17 one-way trips x 40 miles x 2 work periods
= 1,360 mi/month.

Total cost = (1,200 miles + 1,360 miles)(10¢/mi) =
$256/month.

b. Four-wheel drive rental-lease - $1,200/month, unlimited mileage, Ford Bronco.

2. Supervisor

Assume supervisor makes one trip per month to project area. Day of travel each way.

Assume vehicle cost of supervisor is 25¢/mi.

Monthly gas cost: 300 miles x 2 (one-way trips from main office)
600
40 miles x 2 (motel to project) = 80
680 miles

680 miles x 25¢/mi = $170/month.

3. Total Monthly Transportation Cost

1. 4 x 4 vehicle gas cost.........	$256
2. 4 x 4 vehicle lease cost.......	1,200
3. Supervisor vehicle-gas cost....	170
	1,626

SAMPLING SCHEDULE:

20 d/month work schedule

3	d/month travel (1.5 days spent on travel each 10-day work period)
2	d/month laying out "zero" base lines
0.5	d/month sample handling
5.5	days of nonsampling

20 days less 5.5 days of nonsampling = 14.5 days of sampling per month.

Sample rate (from Amselco, Inc., Montana)

1. 30° to 40° slope, average open conditions, 100-ft spacing, 2 persons with Brunton and tape working from previously from Amselco, surveyed base line. Equals 65 samples/d.

   Total samples/month = 65 samples/d x 14.5 days = 942.5 samples/month.

2. Flat and few obstructions, 100-ft sample intervals, estimated 100 samples/8-h day.

   Total samples/month = 100 samples/d x 14.5 days = 1,450 samples/d.

3. Thick underbrush, e.g., blackberries, vine maple, possible swamp.

   - add extra 2 d/month for base line.
   - estimate 25 to 50 samples/d, based on sampling interval (100-, 50-, 25-ft).
   - will use 38 samples/d.

   (38 samples/d)(14.5 days - 2 days) = 475 samples/month.

MISCELLANEOUS FIELD EQUIPMENT COSTS:

Sample Cost:

Assume 70¢/sample. Includes sample bag, label, area map, flagging-marking, and postage. Others would include field clothing and equipment.

Sample Preparation and Drying Prior to Assay (from Amselco, going rate):

Preparation..	$0.80
Drying.......	0.25
Total......	1.05

Total Sample Cost for Miscellaneous Field Equipment and Sample Preparation:

$0.70
1.05
1.75

COST SUMMARY:

Labor (monthly)

Salary...........	$5,386
Per diem.........	2,038
Transportation...	1,626
Total..........	9,050

Initial sampling costs

Condition	Cost per sample[1]	Field equipment and sample preparation	Total cost per sample
Good, 1,450 samples per month.........	$6.24	$1.75	$8.00
Average, 943 samples per month........	9.59	1.75	11.34
Poor, 475 samples per month..........	19.05	1.75	20.80

[1] Based on a $9,050 labor cost per month.

The above costs assume a relatively large long-term sampling program as opposed to a short 1-, 2-, 3-, or so, day sampling program. Per sample cost for the latter case could be substantially larger.

The initial sampling costs were provided to an exploration contractor who is accustomed to doing this type of work. The contractor felt the initial sampling costs were low by $2.00 to $3.00 across the board. The explanation may be that additional in-office expenses are incurred such as planning, programming, plotting, map drafting, analytic plotting, etc.

As a result, the initial per sample costs are increased to $2.50 and the totals are rounded to the nearest higher dollar.

Sampling costs

Condition	Sample rate	Field equipment and sample preparation	Total cost per sample[1]
Good, 1,450 samples per month.........	$7.99	$2.50	$11.00
Average, 943 samples per month........	11.34	2.50	14.00
Poor, 475 samples per month..........	20.80	2.50	24.00

[1] Rounded.

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.1. CLEARING

The curve for clearing during preproduction development is based on estimated costs for medium-light growth on terrain with a side slope of 20% to 50%. Estimate one tree, 0.33 m in diameter, per 40 m^2.

The total cost per hectare is the sum of three separate cost curves (labor, supplies, and equipment operation) having a clearing area (X), in total hectares. The curves are valid for operations between 1 and 1,000 ha (from 500 to 1,000 ha, the costs are expected to remain constant), operating one shift per day. This cost is multiplied by the total hectares cleared to obtain the capital cost. The curves include all daily operating and maintenance costs associated with clearing a land surface for further development.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2{,}171.220(X)^{-0.120}$
The operating labor costs are distributed as follows:

Direct labor...............	84%
Maintenance labor..........	16%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator............	21%	$16.33
Truck driver..............	6%	15.89
General laborer...........	73%	13.66

The average wage for labor is $14.58 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 269.796(X)^{-0.0303}$
For clearing operations from 1 to 500 ha, the supply cost consists of 78% fuel oil (for burning wood and scrub) and 22% tools, cables, and chokers. For operations of 500 to 1,000 ha, the supply cost consists of 83% fuel oil and 17% tools, cables, and chokers.

(E) Equipment Operating Cost $(Y_E) = 667.618(X)^{-0.0672}$
Equipment operating costs consist of 87% for crawler dozers and 13% for trucks, pickups, and chainsaws.

The general equipment cost component distribution is

	Repair parts	Fuel and lube	Tires
Crawler dozers............	51%	49%	-
Trucks, pickups, and chainsaws............	14%	80%	6%

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factor:

Brush factor $(Y_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(Y_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 50% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(Y_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(Y_{S\ 50\%-100\%}) = 1.2$

For clearing on terrain with side slopes greater than 100%,

Side slope factor $(Y_{S\ +100\%}) = 2.5$

Burning Factor When the burning of cleared brush and trees is prohibited due to environmental regulations, the brush and trees will have to be stacked or buried. If burning is prohibited, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.2$

Supply factor $(F_S) = 0.2$

Equipment operation factor $(F_E) = 1.2$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

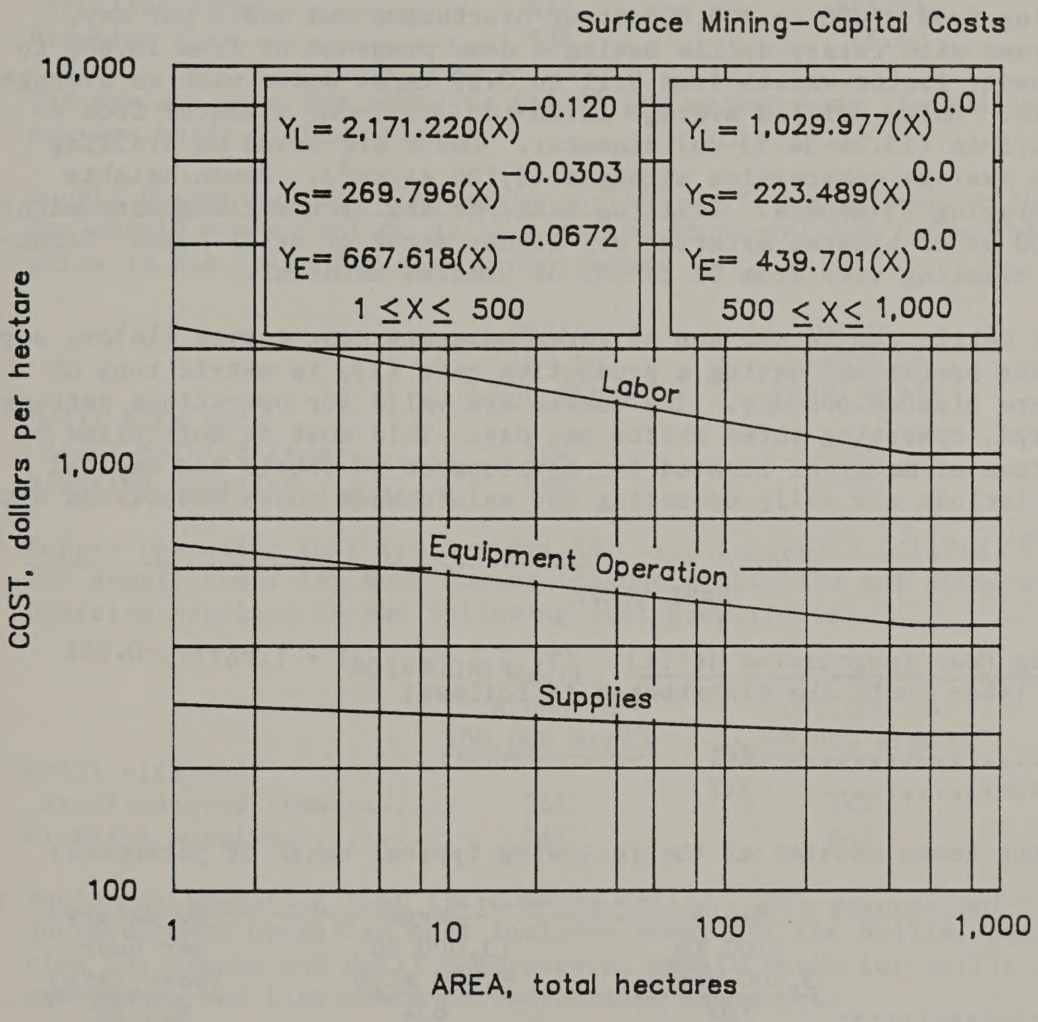
Shifts per day............	1	2	3
Factor....................	1.75	1.56	1.50

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup.

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



2.2.1.1. Clearing

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.3. DRILL AND BLAST OVERBURDEN AND WASTE

The curves have been developed in two parts. For mines excavating from 100 to 8,000 mt of overburden and waste per day, the curves reflect costs for drilling 6-m-high benches with crawler-type percussion drills. Spacing of 2.5-in (6.35-cm) holes is on a pattern of 1.5 by 2 m to a depth of 7 m. The powder factor is 0.30 kg/mt.

For mines excavating from 8,000 to 300,000 mt of overburden and waste per day, drilling is performed with rotary drills having a down pressure of from 13,600 to 56,700 kg. The powder factor varies from 0.11 to 0.20 kg/mt waste with an average of 0.14 kg/mt waste. Holes drilled average 12.25-in (31.12-cm) diameter from a range of 6- to 13.75-in (15.24-34.93-cm) diameter. Costs are based on drilling hard rocks with an average compressive strength (2,100 kg/cm^2). Bench heights are 12 to 18 m averaging 15 meters. Drilling patterns and overdrilling vary with a range of 100 to 300 mt of blasted material per linear meter of drill hole. Secondary drilling and blasting vary from 0% to 10% of blasted material.

The total cost per metric ton is the sum of three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons of overburden and waste blasted per day. The curves are valid for operations between 100 and 300,000 mtpd, operating three shifts per day. This cost is multiplied by the total metric tons of material blasted for development to obtain the capital cost. The curves include all daily operating and maintenance costs associated with drill and blast.

BASE CURVE

(L) Labor Operating Cost (percussion drill) $(Y_{L\ PERCUSSION}) = 1.747(X)^{-0.091}$
The operating labor costs are distributed as follows:

Direct labor...............	76%
Maintenance labor..........	24%

The direct labor costs consist of the following typical range of personnel:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)	Av salary per hour (base rate)
Drilling crew.............	70%	83%	$15.22
Blasting crew.............	30%	17%	14.79

The average wage for labor is $15.41 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (rotary drill) $(Y_{L\ ROTARY}) = 0.0417(X)^{0.0353}$
The operating labor costs are distributed as follows:

Direct labor..............	43%
Maintenance Labor..........	57%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Rotary and secondary drilling crews............	67%	$15.24
Blasting crew..............	33%	15.00

The average wage for labor is $15.45 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (percussion drill) $(Y_{S\ PERCUSSION}) = 30.278(X)^{-0.496}$
The supply costs include drill bits and steel-related items and blasting supplies in the following cost proportions:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)
Drill bits and steel-related items.......	10%	25%
Blasting supplies..........	90%	75%

(S) Supply Operating Cost (rotary drill) $(Y_{S\ ROTARY}) = 0.147(X)^{-0.0160}$
The supply costs for both curves include drill bits and steel-related items and blasting supplies in the following cost proportions:

	Small (8,000 to 100,000 mtpd)	Large (100,000 to 300,000 mtpd)
Drill bits and steel-related items.......	26%	16%
Blasting supplies..........	74%	84%

(E) Equipment Operating Cost (percussion drill) $(Y_{E\ PERCUSSION}) = 1.771(X)^{-0.182}$
The equipment operating cost includes power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating costs for percussion drill and blast are 86% for drilling equipment and 14% for trucks.

The general equipment cost component distribution is

	Repair parts	Fuel and lube	Tires
Percussion drills..........	58%	42%	-
Trucks.....................	8%	87%	5%

(E) Equipment Operating Cost (rotary drill) $(Y_{E\ ROTARY}) = 0.0294(X)^{0.0567}$
The equipment operating cost includes power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating costs for rotary drill and blast are 95% for drilling equipment and 5% for trucks.

The general equipment cost component distribution is

	Repair parts	Fuel and lube	Tires	Power
Rotary drills.............	79%	10%	-	11%
Trucks....................	11%	80%	9%	-

ADJUSTMENT FACTORS

Drill-and-Blast Factor (D & B factor) The curves indicate average costs for a wide range of materials, as can be noted above by drill sizes, bit sizes, powder factors, and drill pattern. To determine drilling and blasting costs, consideration must be given to material hardness, abrasiveness, natural fractures and jointing, and maximum-size fragments that can be loaded, hauled, and processed. Where the above conditions are favorable, multiply the costs obtained from the curves by the following factor:

D & B factor $(F_{D\ GOOD}) = 0.60$

Where the above conditions are unfavorable, multiply the costs by the following factor:

D & B factor $(F_{D\ SEVERE}) = 2.00$

Equipment Factor Where it is necessary to purchase equipment or have a subcontractor perform the work, multiply the cost obtained from the equipment operation curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

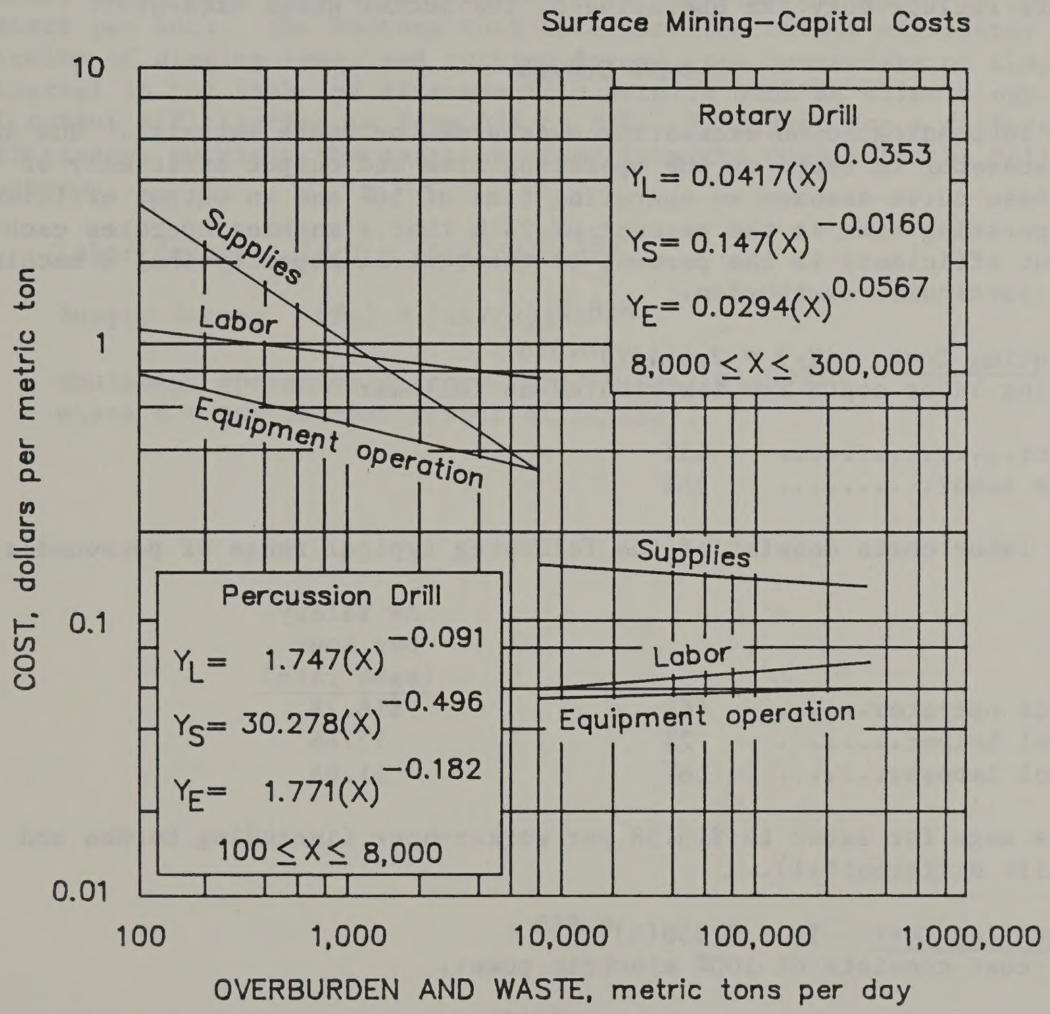
Crawler-type percussion drills:			
Shifts per day..........	1	2	3
Factor..................	1.81	1.61	1.54
Rotary drills:			
Shifts per day..........	1	2	3
Factor..................	1.63	1.47	1.42

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup.

Labor factor $(F_L) = 1.50$

Supply factor $(F_S) = 1.20$

Equipment operation factor $(F_E) = 1.20$



2.2.1.3. Drill and blast
DRILLS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.1. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE
BUCKET WHEEL EXCAVATION

The total capital cost per metric ton is the sum of the three separate cost curves (labor, supplies and equipment operation) having a production rate (X), in metric tons of overburden and waste moved per day. The curves are valid for operations between 2,200 and 125,000 mtpd, operating three shifts per day. The cost is multiplied by the total tons of material mined during development to obtain the capital cost. The costs include only the operation of the bucket wheel excavator.

BASE CURVES

The base curve is predicated on excavating overburden or waste material. The daily output of an excavator is based on the operating time and output efficiency of the machine. The base curve assumes an operating time of 50% and an output efficiency of 46%. The operating time is the percent of 24 h that a machine operates each day. The output efficiency is the percent of theoretical capacity that a machine delivers for a particular overburden.

(L) Labor Operating Cost $(Y_L) = 7.414(X)^{0.556}$
The operating labor costs are distributed as follows:

Direct labor...............	65%
Maintenance labor..........	35%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Bucket wheel operator......	46%	$16.78
Bucket wheel helper........	2%	13.66
Bucket wheel laborer.......	16%	11.68

The average wage for labor is $15.58 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $Y_S = 0.058(X)^{0.859}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $Y_E = 0.212(X)^{0.681}$
The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Shift Adjustment The curve is based on a three-shift-per-day operation. Typically, bucket wheel excavators are run continuously. For a one- or two-shift operation, decrease the operating costs proportionately.

Operating Time Factor The base case assumes a 50% operating time. Bucket wheel excavators do not have high availabilities. The range of expected operating time is 41% to 60%. To adjust for different operating times, multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_T) = [50/(T)]^{0.554}$
where T = new percent operating time.

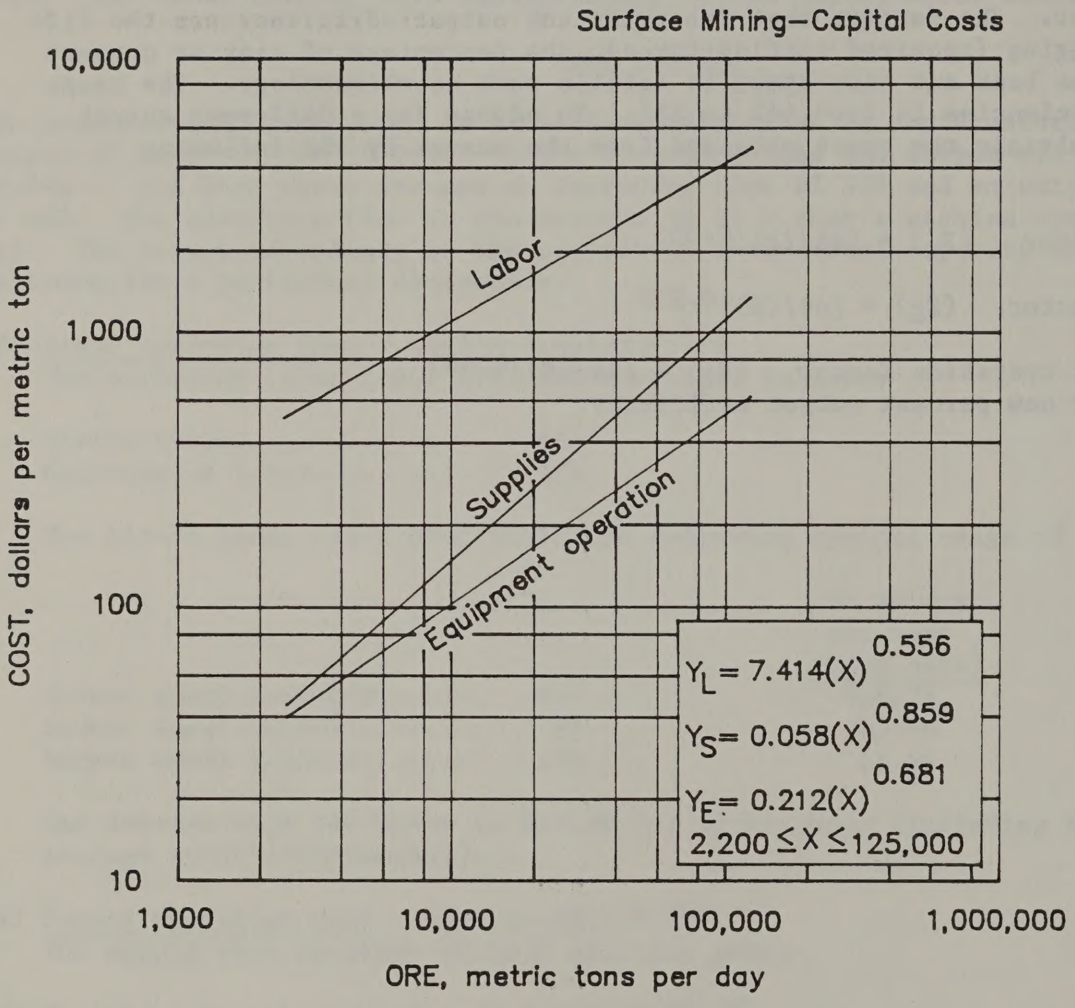
The equipment operation cost curve and supplies cost curves are not modified.

Output Efficiency Factor The output efficiency is the ratio of the actual production to the theoretical capacity of the bucket wheel excavator. The theoretical capacity is based on the number of bucket discharges per minute and the bucket size. The theoretical capacity is normally expressed in loose cubic meters per hour. The factors that determine the output efficiency are the difficulty of digging (required cutting force), the percentage of clay or compact material in the bank and site-specific details such as climatology. The range of output efficiencies is from 44% to 85%. To adjust for a different output efficiency, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [46/(E)]^{0.555}$

Supply factor $(F_S) = [46/(E)]^{0.858}$

Equipment operation factor $(F_E) = [46/(E)]^{0.680}$
where E = new percent output efficiency.



2.2.1.4.1. Excavation, load and haul
BUCKET WHEEL EXCAVATION

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.2. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE DRAGLINE

The curve for draglines covers the cost per metric ton for excavating and casting a medium-digging overburden and waste material from a dry pit into a spoil pile. The material is assumed to weigh 2 mt/m^3 for crawler (diesel-powered) draglines and 1.5 mt/m^3 for walking (electric-powered) draglines.

Crawler draglines range in size from 2- to 20-yd^3 capacity; walking draglines, from 16- to 50-yd^3 capacity. One dozer is provided for each dragline operation for cleanup and support.

The total capital cost per metric ton for crawler draglines is the sum of two separate cost curves (labor and equipment operation) and for walking draglines, the sum of three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons overburden and waste per day. The curve for crawler draglines is valid for a production range of 2,000 to 15,000 mtpd, operating one shift per day; for walking draglines, the curves are valid for a production range of 15,000 to 150,000 mtpd, operating three shifts per day. This cost is multiplied by the total metric tons of material mined during development to obtain the capital cost. The curves include all costs for operating and maintenance costs associated with dragline excavation.

BASE CURVE

(L) Labor Operating Cost (crawler dragline) $(Y_{L\ CRAWLER}) = 43.884(X)^{-0.637}$
The operating labor costs are distributed as follows:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)
Direct labor...............	59%	56%
Maintenance labor..........	41%	44%

The direct labor costs consist of the following typical range of personnel:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)	Av salary per hour (base rate)
Dragline operator..........	41%	26%	$18.11
Oiler......................	24%	22%	15.89
Dozer operator.............	25%	23%	16.33
Utility operator...........	10%	29%	13.66

The average wage for crawler dragline labor is $16.13 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (walking dragline) $(Y_{L\ WALKING}) = 12.249(X)^{-0.458}$
The operating labor costs are distributed as follows:

Direct labor...............	62%
Maintenance labor..........	38%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dragline operator..........	30%	$18.11
Oiler......................	26%	15.89
Dozer operator.............	27%	16.33
Utility operator...........	17%	13.66

The average wage for walking dragline labor is $16.46 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (walking dragline) $(Y_{S\ WALKING}) = 0.0395(X)^{0.003}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost (crawler dragline) $(Y_{E\ CRAWLER}) = 2.218(X)^{-0.312}$
Equipment operating cost distribution for a crawler dragline operation is

Dragline...................	70%
Crawler tractors...........	25%
Pickup trucks..............	5%

(E) Equipment Operating Cost (walking dragline) $(Y_{E\ WALKING}) = 0.533(X)^{-0.166}$
Equipment operating cost distribution for a walking dragline operation is

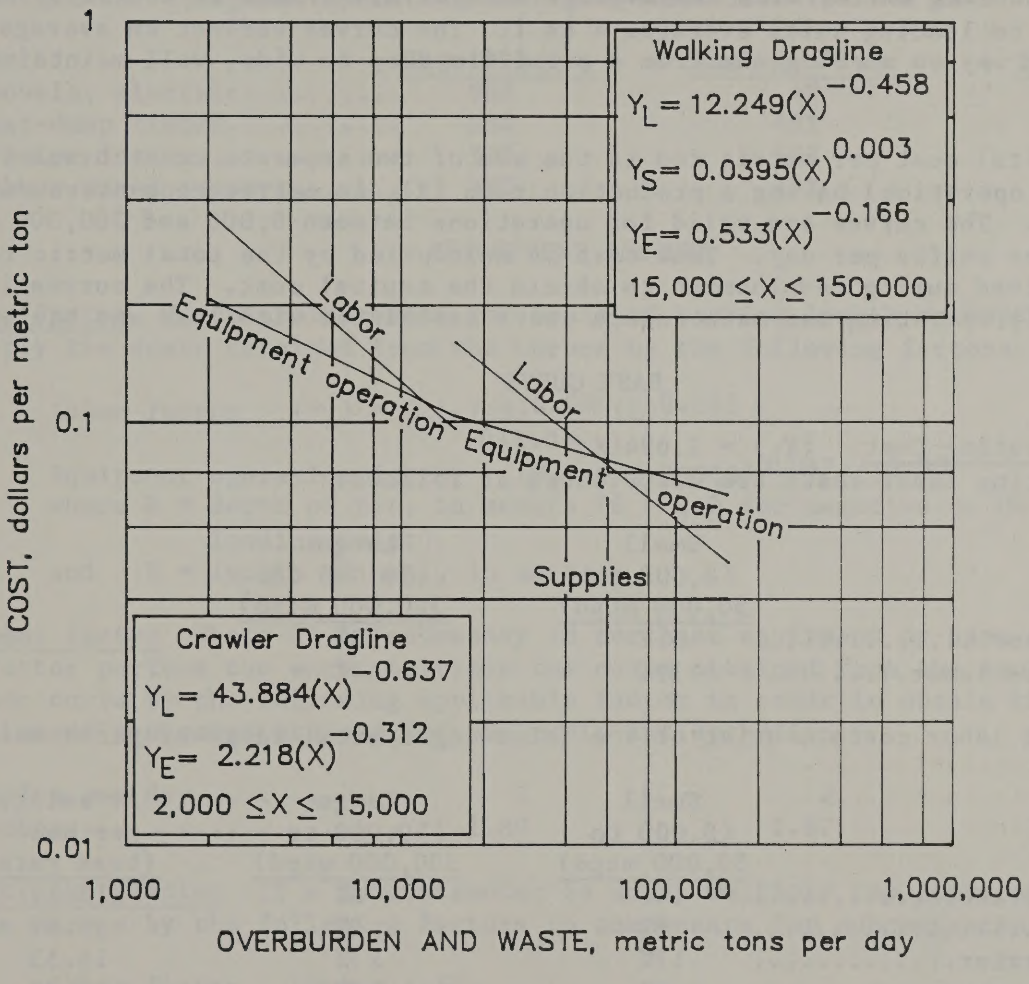
Dragline...................	66%
Crawler tractors...........	31%
Pick-up trucks.............	3%

The general equipment operating cost component distribution for crawler and walking draglines and support equipment is

	Repair parts	Fuel and lube	Tires
Walking draglines..........	94%	6%	-
Crawler draglines..........	65%	35%	-
Crawler dozers.............	49%	51%	-
Rubber-tired support.......	8%	90%	2%

ADJUSTMENT FACTOR

Truck Loading To determine the cost of a crawler dragline operation loading to trucks, use the values obtained from the curve for electric shovels and trucks. Adjust the values by increasing each curve component 25% and combine the equipment operation and supplies curves to account for substitution of diesel fuel for electric power. (NOTE.--Supplies values for the electric shovels and trucks curve include only electric power.)



Surface Mining—Capital Costs

2.2.1.4.2. EXCAVATION, load and haul
DRAGLINE

2.2. SURFACE MINING - CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.3. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE ELECTRIC SHOVEL AND TRUCKS

The curves show the cost per metric ton for excavating, loading, and hauling both common and shot rock. For common earth excavation, 1 bank m^3 equals 2.08 mt; for shot rock, 1 bank m^3 equals 2.61 mt.

The loading units are electric shovels and diesel front-end loaders ranging in size from 5 to 30 yd^3, with an average of 15 yd^3. Rear dump trucks from 35 to 170 st are the main hauling units, with the average size of all trucks at 100 st. The ratio of trucks to loading units averages 6 to 1. The curves reflect an average haul of 2,000 m one way on an 8% grade from a pit 120 m deep on wide, well maintained roads.

The total capital cost per metric ton is the sum of two separate cost curves (labor and equipment operation) having a production rate (X), in metric tons overburden and waste per day. The curves are valid for operations between 8,000 and 300,000 mtpd, operating three shifts per day. This cost is multiplied by the total metric tons of material mined during development to obtain the capital cost. The curves include all daily operating and maintenance costs associated with load and haul.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2.694(X)^{-0.210}$

The operating labor costs are distributed as follows:

	Small (8,000 to 50,000 mtpd)	Large (50,000 to 300,000 mtpd)
Direct labor..............	61%	53%
Maintenance labor.........	39%	47%

The direct labor costs consist of the following typical range of personnel:

	Small (8,000 to 50,000 mtpd)	Large (50,000 to 300,000 mtpd)	Av salary per hour (base rate)
Shovel operator...........	14%	8%	$18.11
Oiler.....................	6%	4%	15.89
Dozer operator............	17%	23%	16.33
Grader operator...........	5%	7%	16.33
Front-end loader operator..	3%	1%	16.33
Truck driver..............	52%	57%	15.89
General laborer...........	3%	-	13.66

The average wage for labor is $16.54 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.188(X)^{-0.220}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.850(X)^{-0.133}$

The equipment operating cost covers the daily operating cost for all excavation, loading, and hauling equipment and includes allowances for repair parts, tires, lubrication, and fuel consumption.

Equipment operating cost distribution for an electric shovel and truck operation is

Shovels....................	7%
Rear-dump trucks...........	70%
Crawler dozers.............	12%
Rubber-tired support.......	11%

The general equipment operating cost component distribution is

	Repair parts	Fuel and lube	Tires
Shovels, electric..........	96%	4%	-
Rear-dump trucks...........	25%	48%	27%
Crawler dozers.............	50%	50%	-
Rubber-tired support.......	35%	47%	18%

ADJUSTMENT FACTORS

Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.117(R)^{0.030}(L)^{0.263}$

Equipment operation factor $(F_E) = 0.055(R)^{0.047}(L)^{0.353}$

where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),

and L = length of haul, in meters.

Equipment Factor Where it is necessary to purchase equipment or have a subcontractor perform the work, multiply the costs obtained from the equipment operation curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

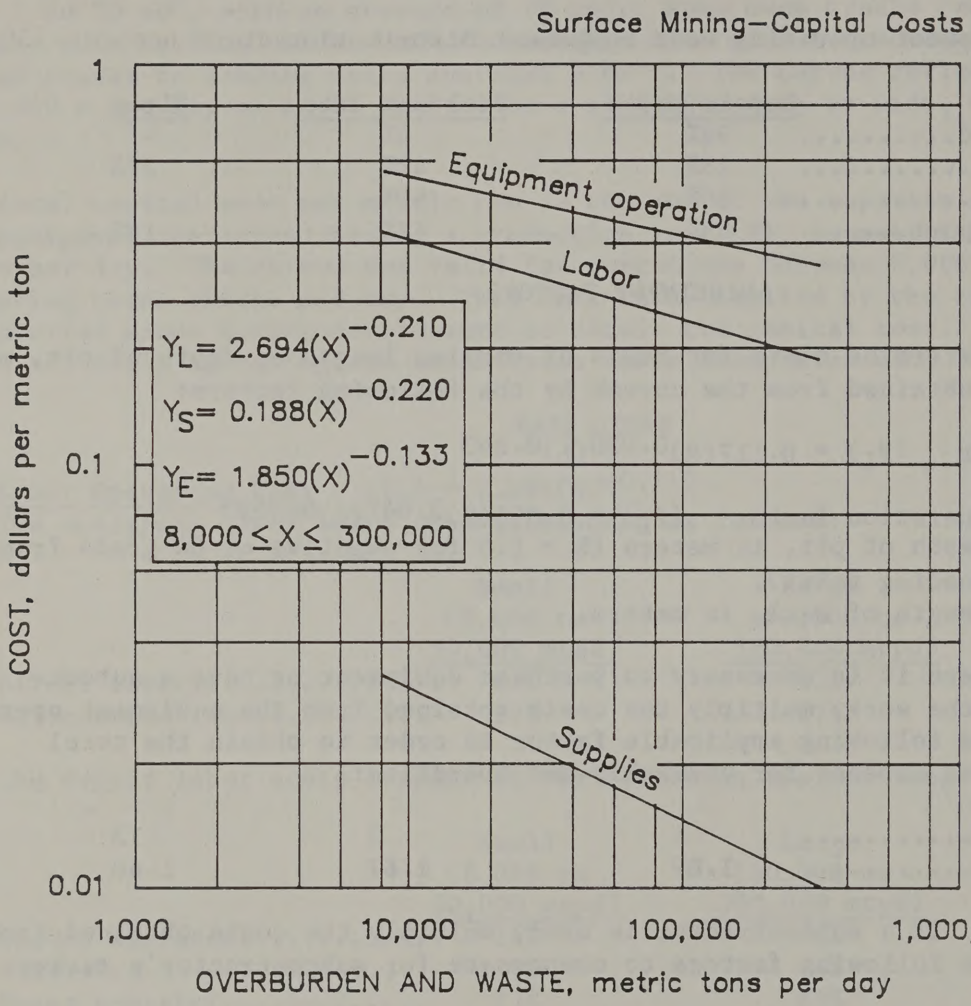
Shifts per day.............	1	2	3
Factor.....................	1.89	1.67	1.60

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup.

Labor factor $(F_L) = 1.50$

Supply factor $(F_S) = 1.20$

Equipment operation factor $(F_E) = 1.20$



2.2.1.4.3. Excavation, load and haul
ELECTRIC SHOVEL AND TRUCKS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.4. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

The curve shows the cost per metric ton for loading and hauling both common and shot rock. For common earth excavation, 1 bank m^3 equals 2.08 mt; for shot rock, 1 bank m^3 equals 2.61 mt.

The curve is based on mines using front-end loaders or diesel shovels for loading and trucks for haulage. The loaders and shovels range in size from 1 to 6 yd^3, and the trucks range from 10 to 35 st. The curves reflect an average haul of 750 m one way on an 8% grade from a pit 60 m deep.

The total capital cost per metric ton is the sum of two separate cost curves (labor and equipment operation) having a production rate (X), in metric tons overburden and waste per day. The curves are valid for operations between 1,000 and 10,000 mtpd, operating two shifts per day. This cost is multiplied by the total metric tons of material mined during development to obtain the capital cost. The curves include all daily operating and maintenance costs associated with excavation, loading, and haulage.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 37.003(X)^{-0.471}$
The operating labor costs are distributed as follows:

Direct labor...............	70%
Maintenance labor..........	30%

The direct labor costs consist of the following typical range of personnel:

	Small (1,000 to 3,000 mtpd)	Large (3,000 to 10,000 mtpd)	Av salary per hour (base rate)
Loader-shovel crew.........	30%	21%	$16.24
Truck haulage crew.........	46%	37%	15.89
Dozer operator.............	24%	17%	16.33
Rubber-tired support crew..	-	25%	16.11

The average wage for labor for operations less than 3,000 mtpd is $16.20 per worker-hour (including burden and average shift differential).

The average wage for labor for operations greater than 3,000 mtpd is $16.42 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 24.620(X)^{-0.424}$
The equipment operating cost distribution for loader/diesel shovel and truck operation is

Loader-shovel..............	18.1%
Rear-dump truck............	42.8%
Crawler dozer..............	23.2%
Rubber-tired support.......	15.9%

The general equipment cost component distribution applies to the following equipment:

	Repair parts	Fuel and lube	Tires
Shovel, diesel.............	69.6%	30.4%	-
Frontend loader............	32.5%	44.2%	23.3%
Rear-dump truck............	28.1%	51.6%	20.3%
Crawler dozer..............	50.6%	49.4%	-
Rubber-tired support.......	28.5%	62.7%	8.8%

ADJUSTMENT FACTORS

Haulage Factor To determine costs for hauls of varying haul length or depth of pit, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.155(R)^{0.030}(L)^{0.263}$

Equipment operation factor $(F_E) = 0.080(R)^{0.047}(L)^{0.353}$
where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),
and L = length of haul, in meters.

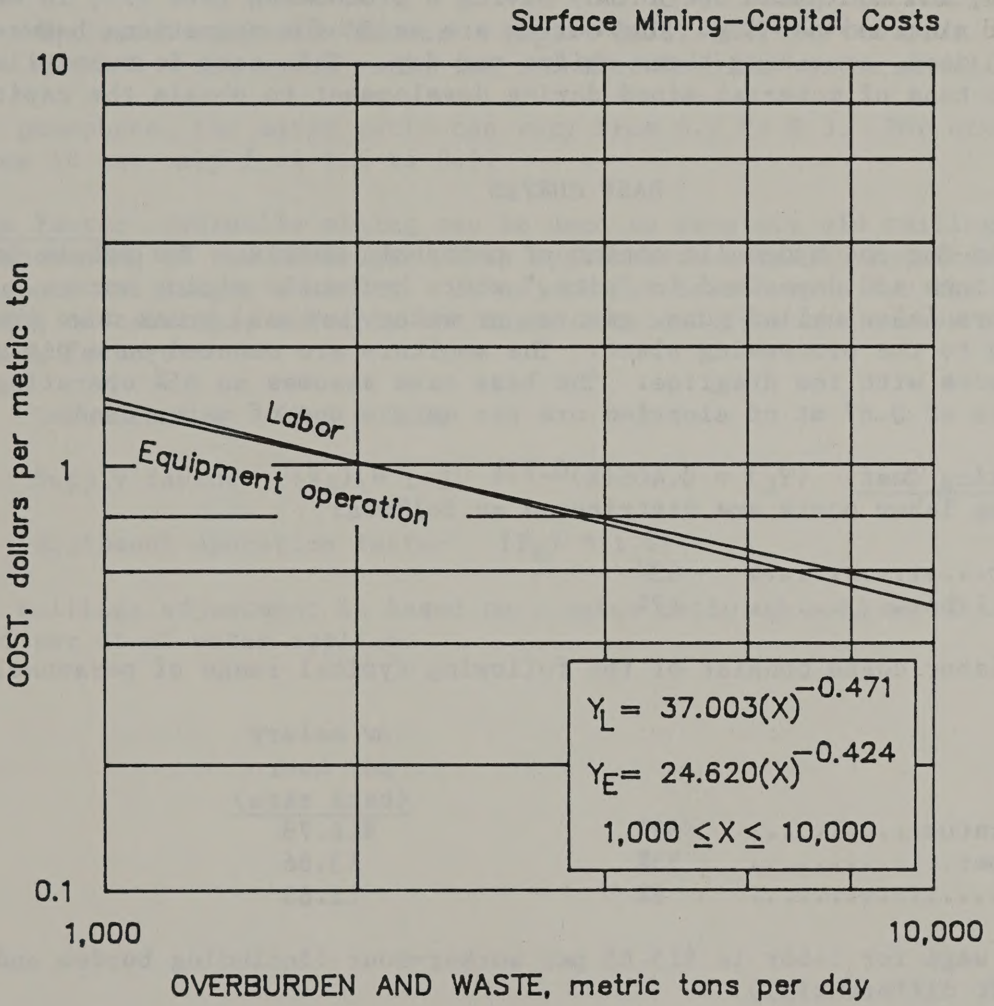
Equipment Factor Where it is necessary to purchase equipment or have a subcontractor perform the work, multiply the cost obtained from the equipment operation curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day........	1	2	3
Factor................	1.84	1.63	1.56

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup.

Labor factor $(F_L) = 1.50$

Equipment operation factor $(F_E) = 1.20$



2.2.1.4.4. Excavation, load and haul
FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.5. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE HYDRAULIC MINING

The operating costs for hydraulic mining are given on a metric ton per day of waste slurried. The costs include the operation of the monitors and high-pressure water pumps. Not included in the estimates is the cost for pumping the slurry. The total capital cost per metric ton is the sum of the three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons of material slurried per day. The curves are valid for operations between 9,500 and 58,000 mtpd, operating three shifts per day. This cost is multiplied by the total metric tons of material mined during development to obtain the capital cost.

BASE CURVES

The base curve is for the hydraulic mining of phosphate matrix. The matrix is excavated by draglines and deposited in "pits," where hydraulic mining occurs. The hydraulic monitors (also called guns, giants, or water cannons) break down the matrix for pumping to the processing plant. The monitors are mounted on a pit gun car, which advances with the dragline. The base case assumes an 85% operating time and a water ratio of 0.67 mt of slurried ore per metric ton of water used.

(L) Labor Operating Cost $(Y_L) = 0.406(X)^{0.771}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Monitor operator...........	59%	$16.78
Monitor helper.............	33%	13.66
Laborer....................	8%	11.68

The average wage for labor is $15.65 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.883(X)^{0.685}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.019(X)^{0.748}$
The equipment operation curve consists of monitor repair parts and materials. The repair costs are divided 30% for water pumps and 70% for the monitor systems (hydraulic pumps, controls and monitors).

ADJUSTMENT FACTORS

Water Ratio Factor Each deposit to be hydraulically mined will require different quantities of water, and therefore, different sizes or numbers of monitors. The more competent (tougher) the deposit, the more water that will be required. The measure of difficulty in slurrying the deposit is the mass ratio of ore excavated to water used. To adjust the base curves for different water requirements, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [0.67/(R)]^{0.050}$

Supply factor $(F_S) = [0.67/(R)]^{1.285}$

Equipment operation factor $(F_E) = [0.67/(R)]^{0.327}$
where R = new water ratio (mt ore slurried)/(mt water used).

For phosphate, the water ratio can vary from 0.7 to 0.3. For other applications it can vary from 1.5 to 0.2.

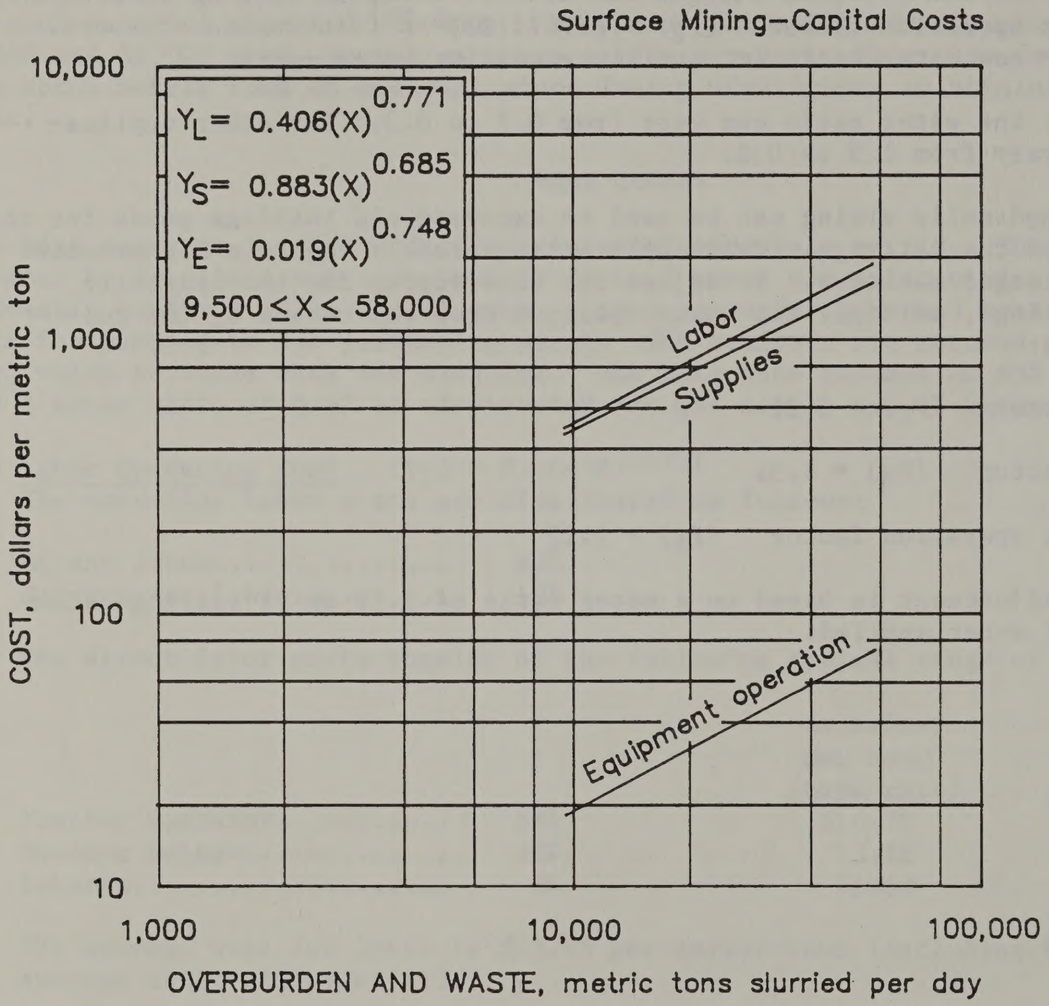
Tailings Factor Hydraulic mining can be used to excavate old tailings ponds for the reprocessing of the tailings. This application normally requires higher water pressure and larger monitors. To adjust the base curves for the hydraulic mining of tailings, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 3.32$

Supply factor $(F_S) = 1.51$

Equipment operation factor $(F_E) = 1.12$

The tailings adjustment is based on a water ratio of 1.22 mt of tailings slurried per mt of water applied.



2.2.1.4.5. Excavation, load and haul
HYDRAULIC MINING

2.2. SURFACE MINING--CAPITAL COSTS

2.2.1. PREPRODUCTION DEVELOPMENT

2.2.1.4.6. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE SCRAPERS

The curves show the cost per metric ton for loading and hauling unconsolidated overburden. Scraper production in metric tons per day is based on an assumed material having a weight of 2.2 mt/m^3 and requiring ripping.

The curves are based on a one-way haul of 900 m on a level grade and include a 6% rolling resistance in the pit area using wheel tractor-scrapers ranging in size and type from 150-hp self-loading elevating scrapers to 550-hp twin-engine scrapers.

The total capital cost per metric ton is the sum of two separate cost curves (labor and equipment operation) having a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 2,000 and 300,000 mtpd, operating three shifts per day. This cost is multiplied by the total tons of material mined during development to obtain the capital cost. The curves include all daily operating and maintenance costs associated with load and haul.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 3.831(X)^{-0.265}$

The operating labor costs are distributed as follows:

Direct labor...............	47%
Maintenance labor.........	53%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Scraper operator.............	58%	$17.33
Crawler operator.............	32%	16.33
Rubber-tired support operator.	10%	16.11

The average wage for labor is $16.64 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 0.602(X)^{-0.0747}$

The equipment operating cost distribution for a scraper operation is

Scraper....................	71%
Crawler-dozer..............	24%
Rubber-tired support.......	5%

The general equipment cost component distribution applies to the following equipment:

	Repair parts	Fuel and lube	Tires
Scraper....................	38%	47%	15%
Crawler-dozer.............	53%	47%	-
Rubber-tired support.......	36%	52%	12%

ADJUSTMENT FACTORS

Haulage Factor To determine costs for varying haul lengths and grades, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.0865(L)^{0.359}(G)^{1.530}$

Equipment operation factor $(F_E) = 0.0641(L)^{0.403}(G)^{1.620}$

where L = length of haul, in meters,

and G = grade [defined as 1.0 plus or minus percent grade/100].

Ripping Factor If no ripping is required, multiply the costs obtained from the curves by the following factor:

Ripping factor $(F_R) = 0.85$

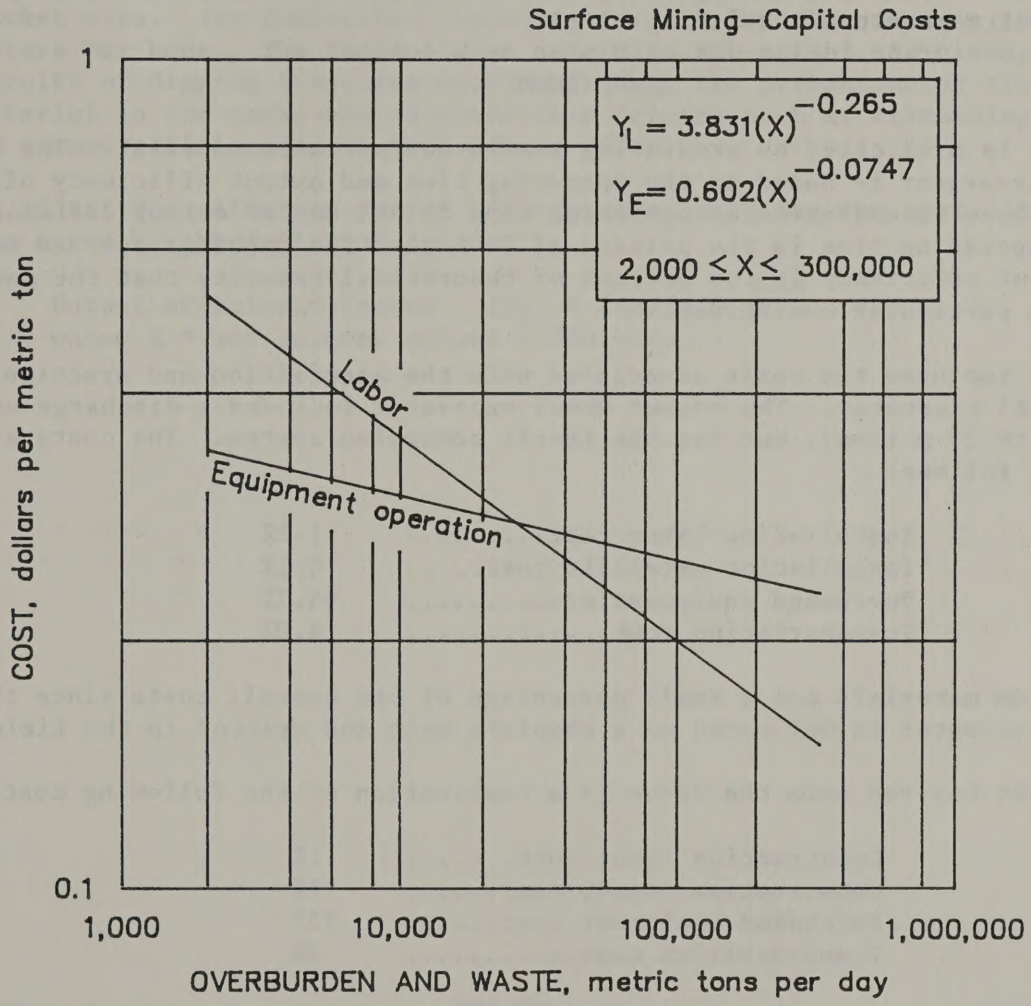
Equipment Factor Where it is necessary to purchase equipment or have a subcontractor perform the work, multiply the cost obtained from the equipment operation curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day............	1	2	3
Factor....................	1.76	1.57	1.51

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup:

Labor factor $(F_L) = 1.50$

Equipment operation factor $(F_E) = 1.20$



2.2.1.4.6. Excavation, load and haul
SCRAPERS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.2. EXCAVATION, LOAD AND HAUL ORE BUCKET WHEEL EXCAVATORS

The capital cost for bucket wheel excavation is for the acquisition and erection of bucket wheel excavators. The bucket wheel excavator is a single unit includes an excavating wheel, transporter, and discharge conveyor. The total capital cost is based on a single cost curve having an excavation rate (X), in metric tons of ore per day. The curve is valid for operations between 2,200 and 125,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on excavating overburden or waste material. The daily output of an excavator is based on the operating time and output efficiency of the machine. The base case assumes an operating time of 50% and an output efficiency of 46%. The operating time is the percent of 24 h that the machines operate each day. The output efficiency is the percent of theoretical capacity that the machine delivers for a particular overburden.

The total cost includes the costs associated with the acquisition and erection of the bucket wheel excavator. The bucket wheel excavator includes a discharge conveyor (from 8 to 25 m long), but not the in-pit conveying system. The costs are distributed as follows:

Installation labor cost.........	1.2%
Installation materials cost.....	0.1%
Purchased equipment cost........	94.7%
Transportation cost.............	4.0%

The installation materials are a small percentage of the overall costs since the bucket wheel excavator is delivered as a complete unit and erected in the field.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	1%
Construction supply cost......	1%
Purchased equipment cost......	95%
Transportation cost...........	3%

The total capital cost is $(Y_C) = 1,660.446(X)^{0.684}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 16.604(X)^{0.684}$

(S) Construction Supply Cost $(Y_S) = 16.604(X)^{0.684}$

(E) Purchased Equipment Cost $(Y_E) = 1,627.238(X)^{0.684}$

ADJUSTMENT FACTORS

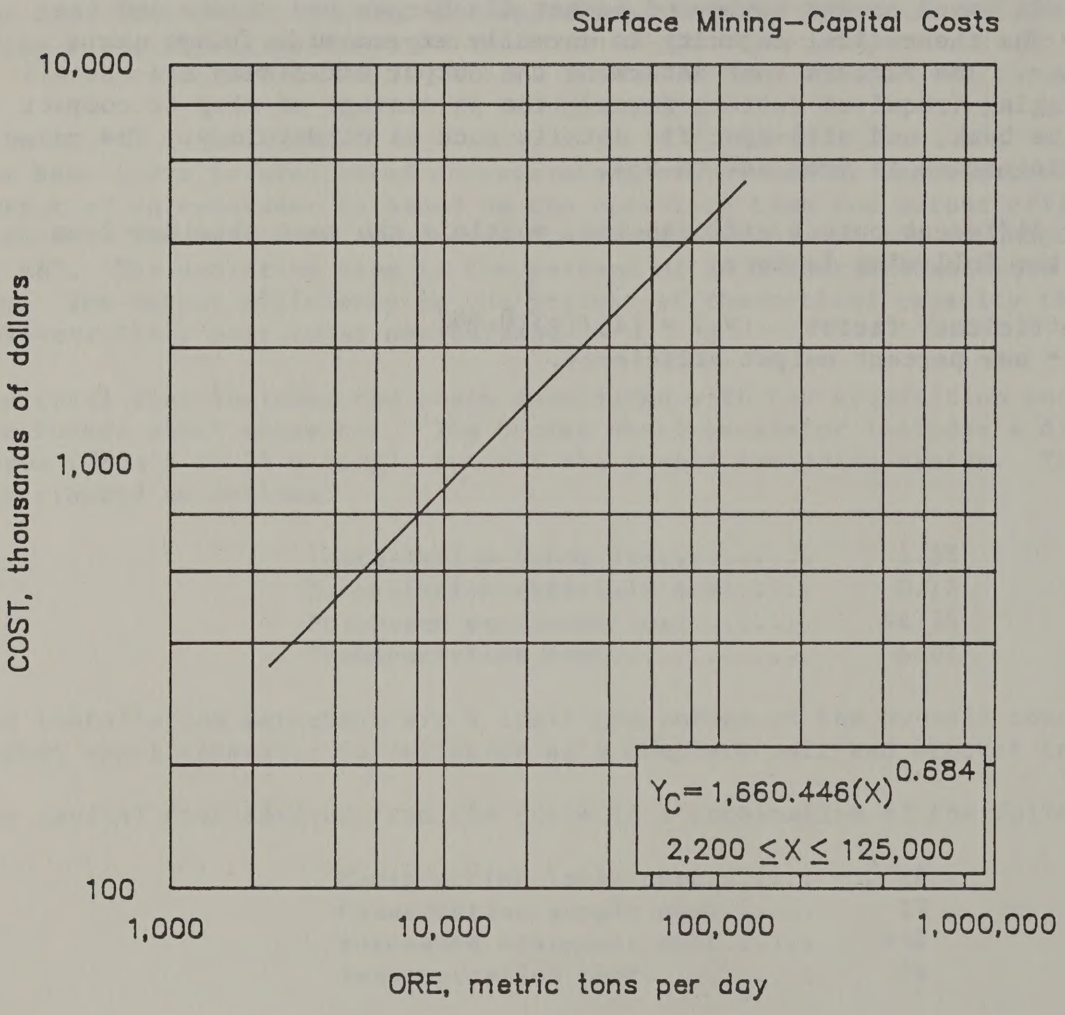
Operating Time Factor The base case assumes a 50% operating time. Bucket wheel excavators do not have high availabilities. The range of expected operating time is 41% to 60%. To adjust for different operating times, multiply the cost obtained from the curve by the following factor:

Operating time factor $(F_T) = [50/(T)]^{0.683}$
where T = new percent operating time.

Output Efficiency Factor The output efficiency is the ratio of the actual production to the theoretical capacity of the bucket wheel excavator. The theoretical capacity is based on the number of bucket discharges per minute and the bucket size. The theoretical capacity is normally expressed as loose cubic meters per hour. The factors that determine the output efficiency are the difficulty of digging (required cutting force), the percentage of clay or compact material in the bank, and site-specific details such as climatology. The range of output efficiencies is from 44% to 85%.

To adjust for different output efficiencies, multiply the cost obtained from the curve by the following factor:

Output efficiency factor $(F_E) = [46/(E)]^{0.682}$
where E = new percent output efficiency.



2.2.2.2. Excavation, load and haul
BUCKET WHEEL EXCAVATORS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.3. EXCAVATION, LOAD AND HAUL ORE DRAGLINE

The following cost curve is for the purchase of surface mining equipment. Preproduction development work can be done using the equipment purchased for operating the mine; however, no reduction in the capital cost should be made if a subcontractor brings in his own equipment.

The cost is predicated upon the equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. It also includes provision for standby equipment and an allowance for miscellaneous items. Escalation for purchased equipment should be factored by the Bureau of Labor Statistics equipment cost index.

The types of equipment covered in the cost curve are all classes of mobile and stationary machinery regularly found in surface mining, including compressors, drills, powder trucks, hydrocranes, wheel loaders, shovels, draglines, crawler dozers and rippers, on-highway and off-highway trucks, and administrative and maintenance equipment not previously included in other sections. The cost for other fixed supporting items, such as power transmission lines and some mobile support items such as fuel trucks, have been included with other capital cost items.

The total capital cost is based on a single cost curve having an production rate (X), in metric tons of material per day. The curve for crawler draglines is valid for a production range of 2,000 to 15,000 mtpd, operating one shift per day; for walking draglines, the curves are valid for a production range of 15,000 to 150,000 mtpd, operating three shifts per day.

BASE CURVE

The curve includes all costs associated with the purchase and installation of all surface mine equipment. The cost for fixed supporting items such as electric power transmission lines has been covered where specifically noted in other items.

The capital cost derived from the dragline curves is a combination of the following costs:

Construction labor cost.......	20%
Construction supply cost......	1%
Purchased equipment cost......	77%
Transportation cost...........	2%

A typical breakdown of the major cost components is

Crawler dragline:	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)
Draglines..................	64%	79%
Auxiliary equipment........	36%	21%

Walking dragline:

Draglines............	97% (includes 20% erection cost)
Auxiliary equipment..	3%

The total capital cost for a crawler dragline operation is $(Y_{C\ CRAWLER}) = 1{,}069.304(X)^{0.803}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ CRAWLER}) = 213.608(X)^{0.803}$

(S) Construction Supply Cost $(Y_{S\ CRAWLER}) = 10.693(X)^{0.803}$

(E) Purchased Equipment Cost $(Y_{E\ CRAWLER}) = 844.750(X)^{0.803}$

The total capital cost for a walking dragline operation is $(Y_{C\ WALKING}) = 1{,}054.727(X)^{0.904}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ WALKING}) = 210.945(X)^{0.904}$

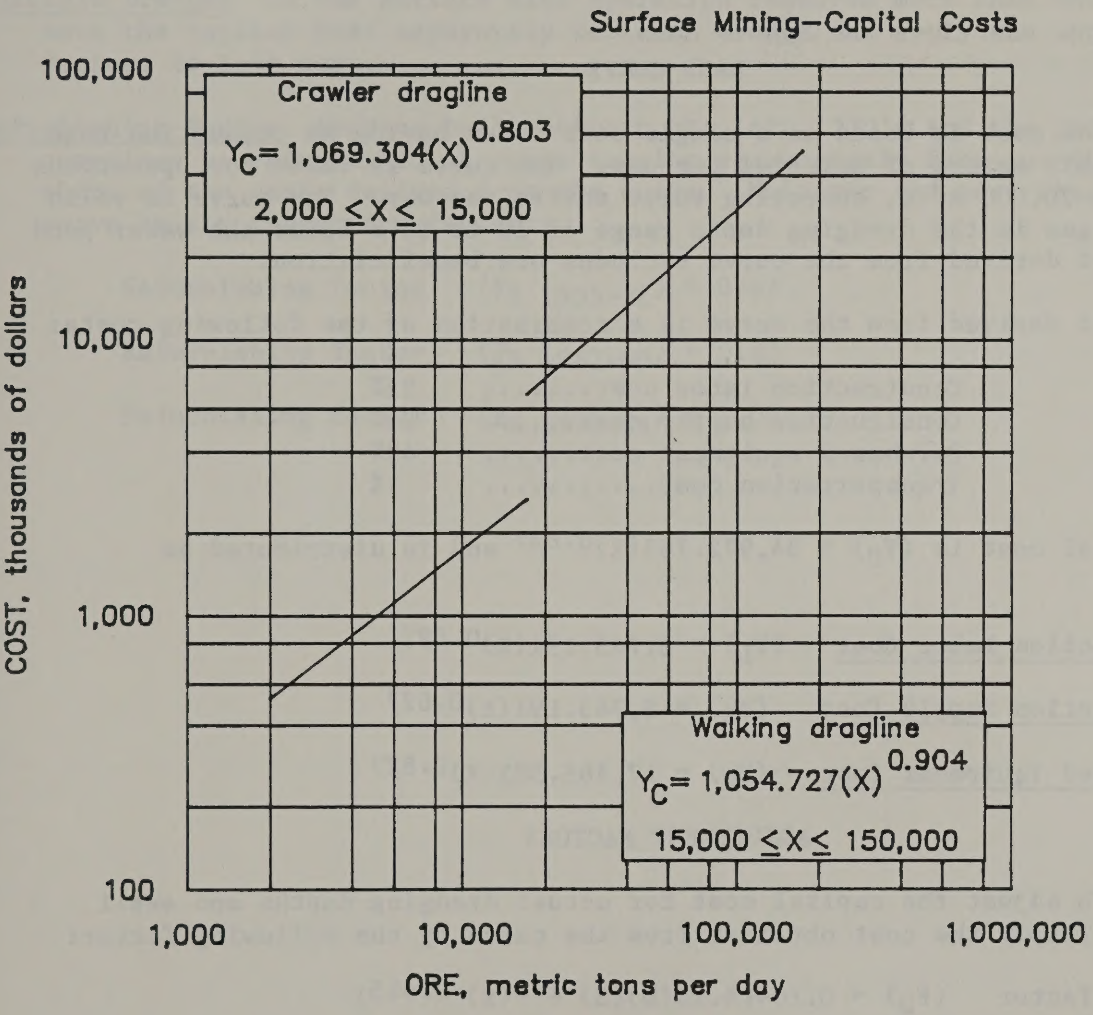
(S) Construction Supply Cost $(Y_{S\ WALKING}) = 10.547(X)^{0.904}$

(E) Purchased Equipment Cost $(Y_{E\ WALKING}) = 841.567(X)^{0.904}$

ADJUSTMENT FACTOR

Haulage Where trucks are used in combination with crawler draglines, use loader and truck, or shovel and truck, curves and multiply by the appropriate hauling equipment component to obtain the truck haulage capital equipment cost, and add this cost obtained to the crawler dragline curve.

To determine the cost where further handling of material is required from a walking dragline operation, add the cost derived from the electric shovel and truck curve multiplied by a factor of 0.89 (drill and blast equipment, 11% of the total, would not be required).



2.2.2.3. Excavation, load and haul
DRAGLINE

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.4. EXCAVATION, LOAD AND HAUL ORE
DREDGE

Bucket line dredges are generally designed and configured for a specific mining application. For this reason, a generalized cost model cannot be accurately applied in capital cost estimating. However, for the manual user's guidance, the cost curve below provides a generalized estimate of capital costs, which should be used with caution.

BASE CURVE

The total capital cost is based on a single cost curve having an production rate (X), in bank cubic meters of material per day. The curve is valid for operations between 500 and 20,000 m^3/d, operating three shifts per day. The curve is valid for single dredges in the dredging depth range of 10 to 50 m below the water pond level. The cost derived from the curve excludes ore beneficiation.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	25%
Construction supply cost......	25%
Purchased equipment cost......	49%
Transportation cost...........	1%

The total capital cost is $(Y_C) = 34{,}972.765(X)^{0.627}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 8{,}743.191(X)^{0.627}$

(S) Construction Supply Cost $(Y_S) = 8{,}743.191(X)^{0.627}$

(E) Purchased Equipment Cost $(Y_E) = 17{,}486.382(X)^{0.627}$

ADJUSTMENT FACTORS

Depth Factor To adjust the capital cost for actual dredging depths and swell factors, multiply the cost obtained from the curve by the following factor:

Depth factor $(F_D) = 0.10+[6.86(D)(S)^{-1.0}(X)^{-0.615}]$
where D = actual depth, in meters,
S = actual swell factor (the reciprocal of one plus the decimal equivalent of percent swell). The base swell factor is 0.80,
and X = volume to be dredged, in bank cubic meters per day.

Mineral Processing Factor To include the capital cost of a mineral processing plant (i.e., jigging or other gravity separation method) mounted on the dredge, multiply the cost obtained from the curve by one of the following factors:

Minimal mineral processing:

Mineral processing factor $(F_{M\ MINIMAL}) = 1.25$

Some mineral processing:

Mineral processing factor $(F_{M\ SOME}) = 1.37$

Complex mineral processing:

Mineral processing factor $(F_{M\ COMPLEX}) = 1.50$

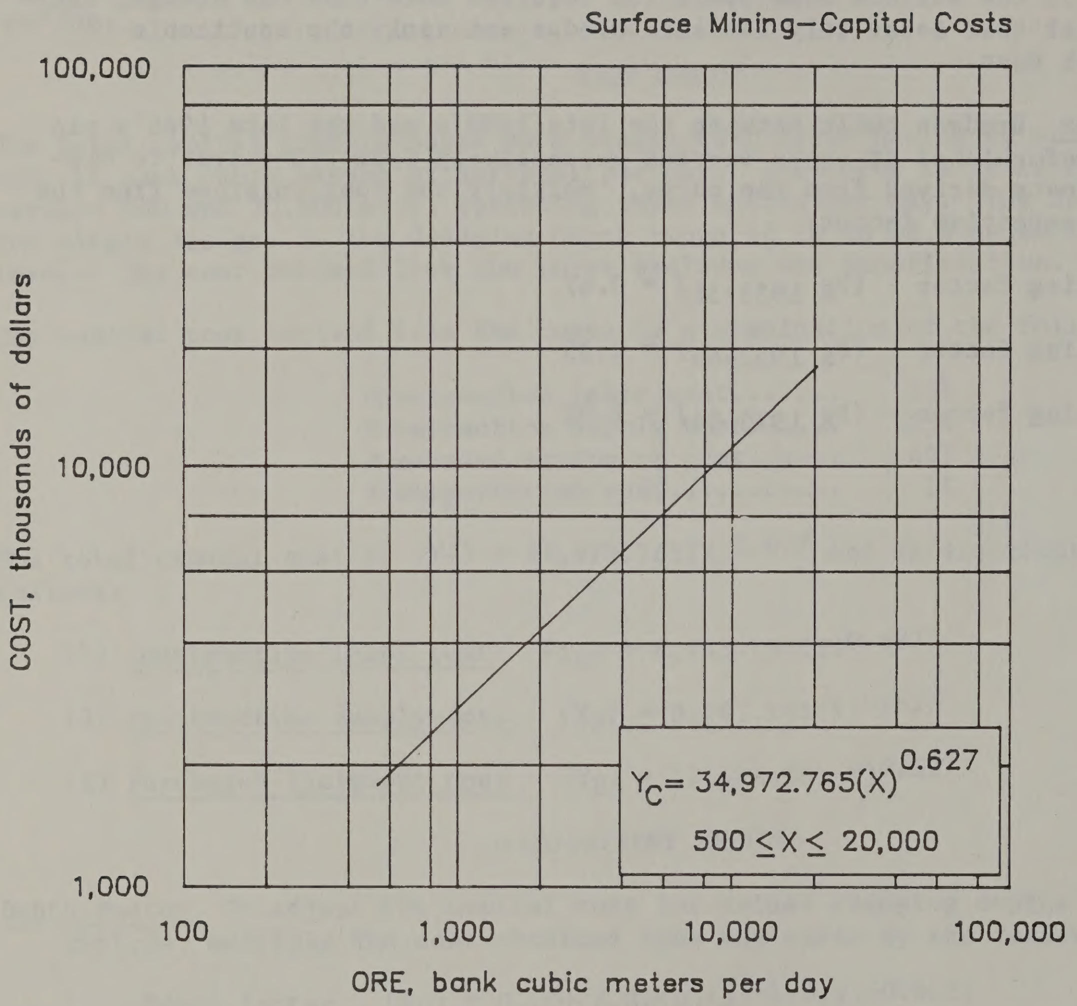
Multiple Dredges If the surface mine operation requires more than one dredge, estimate the capital cost separately for each dredge and apply the applicable factors to each cost.

Refurbishing Factor Dredges built between the late 1930's and the late 1960's can sometimes be refurbished at costs varying respectively from two-thirds to one-third of the costs derived from the curve. Multiply the cost obtained from the curve by its respective factor:

Refurbishing factor $(F_{R\ 1935-51}) = 0.67$

Refurbishing factor $(F_{R\ 1952-69}) = 0.33$

Refurbishing factor $(F_{R\ 1970-84}) = 1.00$



2.2.2.4. Excavation, load and haul
DREDGE

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.5. EXCAVATION, LOAD AND HAUL ORE ELECTRIC SHOVEL AND TRUCKS

The following cost curve is for the purchase of surface mining equipment. Preproduction development work can be done using the equipment purchased for operating the mine; however, no reduction in the capital cost should be made if a subcontractor brings in his own equipment.

The total capital cost is based on a single cost curve having an production rate (X), in metric tons of ore per day. The curve is valid for a production range of 8,000 to 400,000 mtpd, operating three shifts per day.

BASE CURVE

The cost is predicated upon the equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. It also includes provision for standby equipment and an allowance for miscellaneous items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	4%
Construction supply cost.......	6%
Purchased equipment cost.......	88%
Transportation cost............	2%

A typical breakdown of the major cost components is

Loading equipment............	30%
Hauling equipment............	59%
Drill and blast equipment.....	11%

The total equipment capital cost for electric shovel and truck operation is $(Y_C) = 5{,}281.346(X)^{0.782}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 211.254(X)^{0.782}$

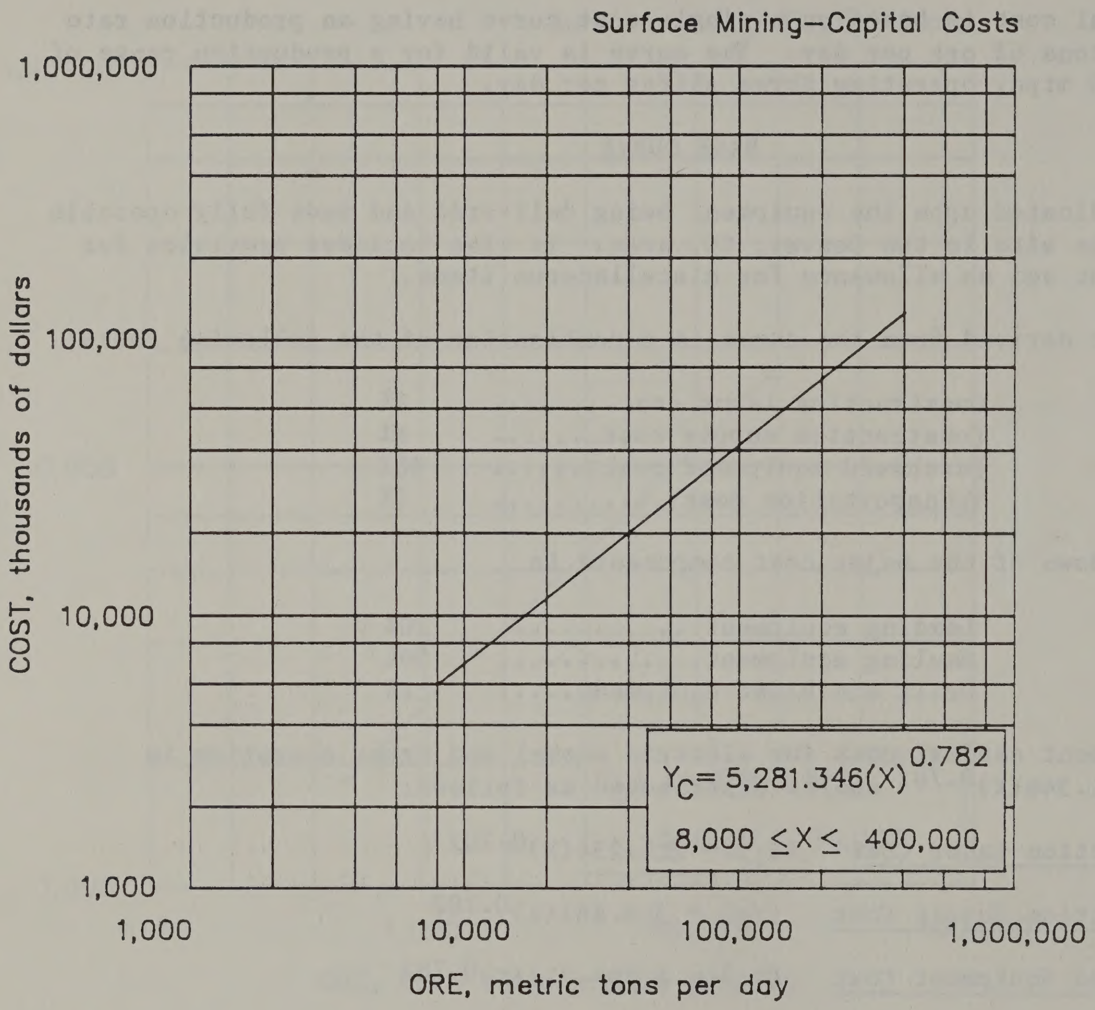
(S) Construction Supply Cost $(Y_S) = 316.881(X)^{0.782}$

(E) Purchased Equipment Cost $(Y_E) = 4{,}753.211(X)^{0.782}$

ADJUSTMENT FACTOR

Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the cost obtained from the base curve by the following factor:

Haulage factor $(F_H) = 0.0546(R)^{0.047}(L)^{0.353}$
where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),
and L = length of haul, in meters



2.2.2.5. Excavation, load and haul
ELECTRIC SHOVEL AND TRUCKS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.6. EXCAVATION, LOAD AND HAUL ORE FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

The following cost curves are for the purchase of surface mining equipment and are based on mines operating three shifts per day. Preproduction development work can be done using the equipment purchased for operating the mine; however, no reduction in the capital cost should be made if a subcontractor brings in his own equipment.

The total capital cost is based on a single cost curve having an production rate (X), in metric tons of ore per day. The curve is valid for a production range of 1,000 to 10,000 mtpd, operating three shifts per day.

BASE CURVE

The cost is predicated upon the equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. It also includes provision for standby equipment and an allowance for miscellaneous items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	4%
Construction supply cost.......	6%
Purchased equipment cost.......	88%
Transportation cost...........	2%

A typical breakdown of the major cost components is

	Small (1,000 to 3,000 mtpd)	Large (3,000 to 10,000 mtpd)
Loading equipment........	41%	22%
Hauling equipment........	40%	51%
Drill and blast equipment	19%	27%

The total equipment capital cost for front-end loader or diesel shovel and truck operation is $(Y_C) = 88{,}064.416(X)^{0.407}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 3{,}522.577(X)^{0.407}$

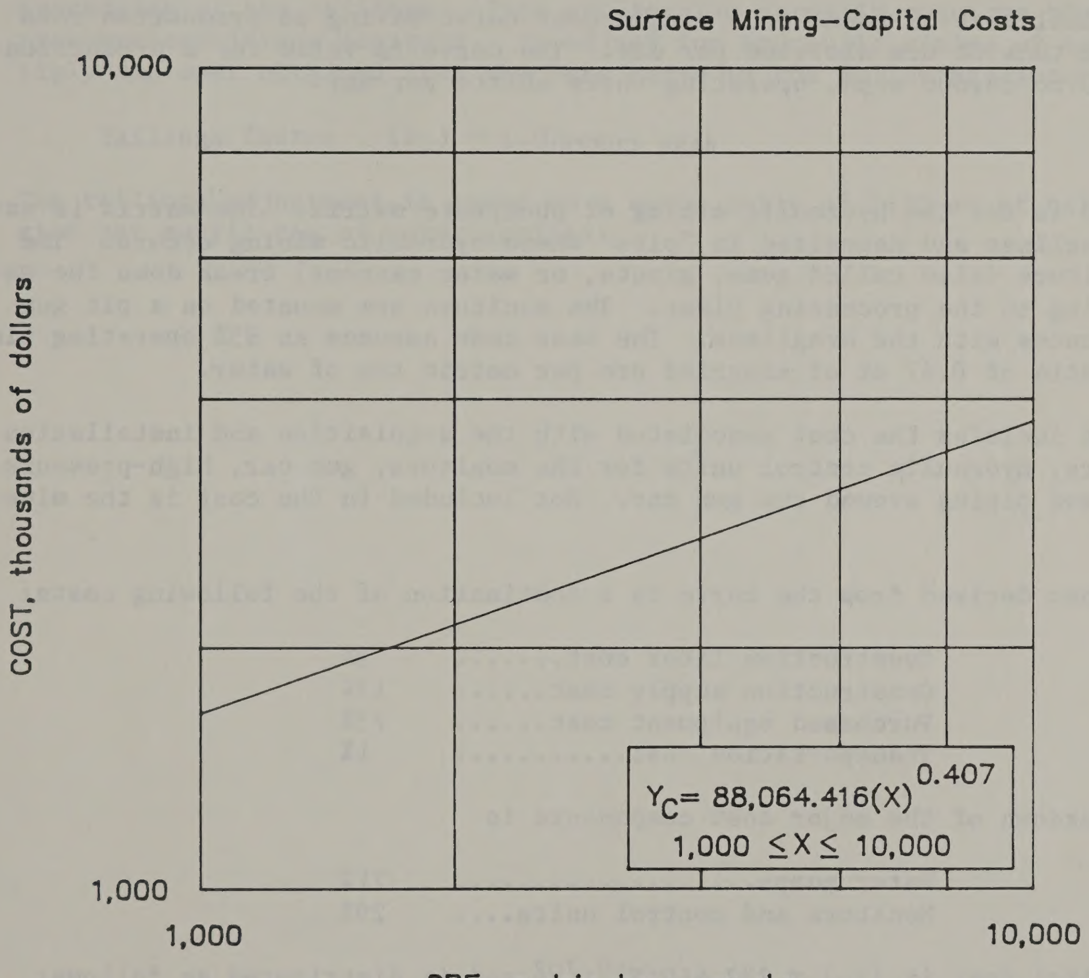
(S) Construction Supply Cost $(Y_S) = 5{,}283.865(X)^{0.407}$

(E) Purchased Equipment Cost $(Y_E) = 79{,}257.974(X)^{0.407}$

ADJUSTMENT FACTOR

Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the cost obtained from the base curve by the following factor:

Haulage factor $(F_H) = 0.080(R)^{0.047}(L)^{0.353}$
where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),
and L = length of haul, in meters.



2.2.2.6. Excavation, load and haul
FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.7. EXCAVATION, LOAD AND HAUL ORE HYDRAULIC MINING

The capital cost for hydraulic mining is for the acquisition and installation of equipment needed to excavate or fluidize an ore. The hydraulic mining unit operation includes the monitor, hydraulic controls and pumps for the monitors, control cab, and high-pressure water pumps.

The total capital cost is based on a single cost curve having an production rate (X), in metric tons of ore slurried per day. The curve is valid for a production range of 9,500 to 58,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is for the hydraulic mining of phosphate matrix. The matrix is excavated by draglines and deposited in "pits" where hydraulic mining occurs. The hydraulic monitors (also called guns, giants, or water cannons) break down the matrix for pumping to the processing plant. The monitors are mounted on a pit gun car which advances with the draglines. The base case assumes an 85% operating time and a water ratio of 0.67 mt of slurried ore per metric ton of water.

The total cost includes the cost associated with the acquisition and installation of the monitors, hydraulic control units for the monitors, gun car, high-pressure water pumps, and piping around the gun car. Not included in the cost is the mine water system.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	9%
Construction supply cost......	15%
Purchased equipment cost......	75%
Transportation cost...........	1%

A typical breakdown of the major cost components is

Water pumps...................	71%
Monitors and control units....	29%

The total capital cost is $(Y_C) = 232.640(X)^{0.702}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 20.938(X)^{0.702}$

(S) Construction Supply Cost $(Y_S) = 34.896(X)^{0.702}$

(E) Purchased Equipment Cost $(Y_E) = 176.806(X)^{0.702}$

ADJUSTMENT FACTORS

Water Ratio Factor Each deposit to be hydraulically mined will require different quantities of water and therefore different sizes or numbers of monitors. The more competent the deposit, the more water that will be used. The measure of difficulty in slurrying the deposit is the mass ratio of ore excavated to water used. To adjust for different water requirements, multiply the cost obtained from the base curve by the following factor:

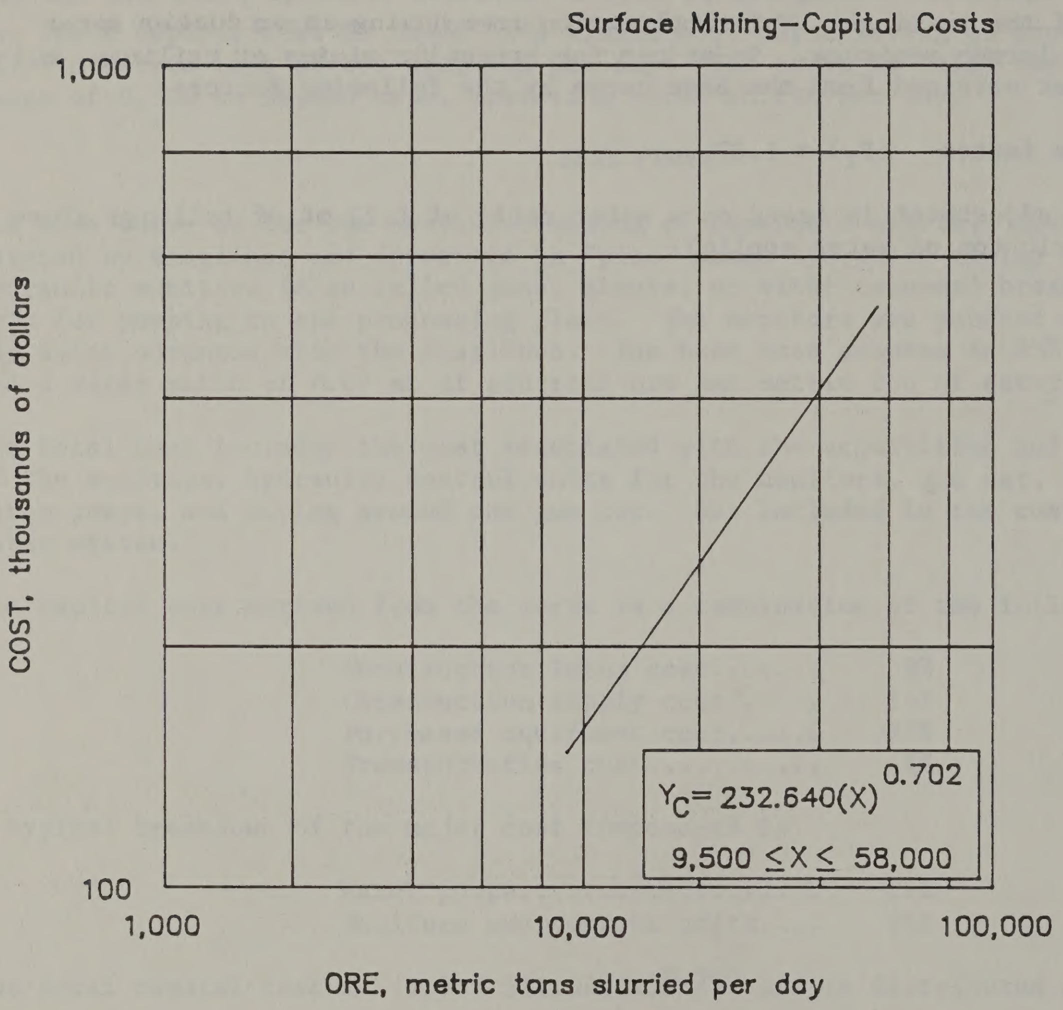
Water ratio factor $(F_R) = [0.670/(R)]^{0.548}$
where R = new water ratio (mt ore slurried)/(mt water used).

For phosphate, the water ratio can vary from 0.3 to 0.7. For other applications it can vary from 0.2 to 1.5.

Tailings Factor Hydraulic mining can be used to excavate tailings ponds for the reprocessing of the tailings. This application normally requires higher water pressure and larger monitors. To adjust for hydraulic mining of tailings, multiply the cost obtained from the base curve by the following factor:

Tailings factor $(F_T) = 1.07$

The tailings adjustment is based on a water ratio of 1.22 mt of tailings slurried per metric ton of water applied.



2.2.2.7. Excavation, load and haul
HYDRAULIC MINING

2.2. SURFACE MINING--CAPITAL COSTS

2.2.2. MINING EQUIPMENT

2.2.2.8. EXCAVATION, LOAD AND HAUL ORE SCRAPERS

The following cost curve is for the purchase of surface mining equipment and is based on mines operating three shifts per day. Preproduction development work can be done using the equipment purchased for operating the mine; however, no reduction in the capital cost should be made if a subcontractor brings in his own equipment.

The total capital cost is based on a single cost curve having an production rate (X), in metric tons of ore per day. The curve is valid for a production range of 2,000 to 250,000 mtpd, operating three shifts per day.

BASE CURVE

The cost is predicated upon the equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. It also includes provision for standby equipment and an allowance for miscellaneous items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	4%
Construction supply cost......	6%
Purchased equipment cost......	88%
Transportation cost...........	2%

A typical breakdown of the major cost components is:

Scrapers......................	66%
Pit equipment (crawler dozers).	26%
Road equipment (graders, water trucks, pickup trucks)........	8%

The total equipment capital cost for scraper operation is $(Y_C) = 1{,}950.766(X)^{0.761}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 78.031(X)^{0.761}$

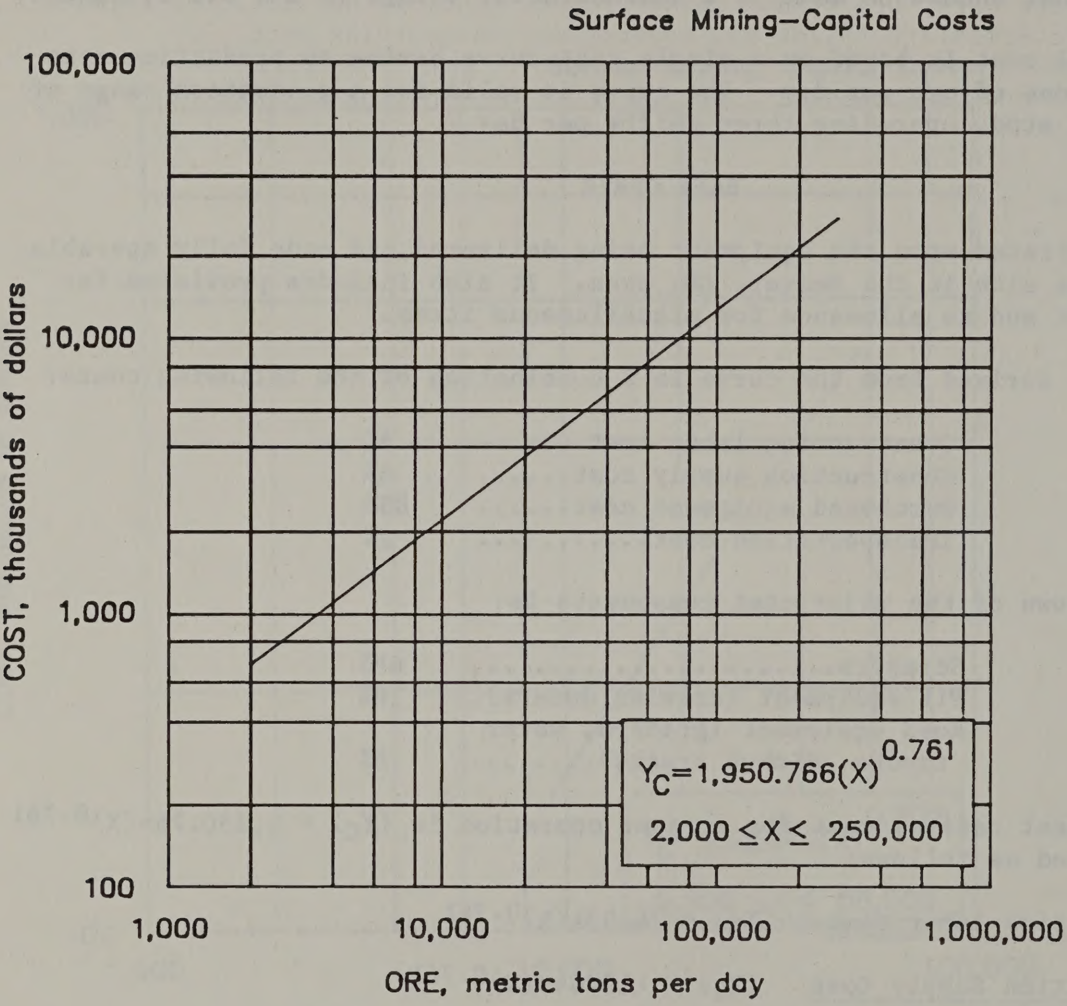
(S) Construction Supply Cost $(Y_S) = 117.046(X)^{0.761}$

(E) Purchased Equipment Cost $(Y_E) = 1{,}755.689(X)^{0.761}$

ADJUSTMENT FACTOR

Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the cost obtained from the base curve by the following factor:

Haulage factor $(F_H) = 0.064(L)^{0.403}(G)^{1.620}$
where L = length of haul, in meters,
and G = grade (defined as 1.0 plus or minus percent grade/100).



2.2.2.8. Excavation, load and haul
SCRAPERS

2.2. SURFACE MINING--CAPITAL COSTS

2.2.3. TRANSPORTATION

2.2.3.1. AERIAL TRAMWAY

The capital cost curve for the aerial tramway is for the acquisition and installation of equipment for transporting ore or waste material over a slope distance of 3 km at a slope angle of 15°. The bulk density of the material was assumed at 1,442.5 km/m^3 (92.0 lb/ft^3). The aerial tramway system includes loading bin, apron feeders, tram cars, track and haulage ropes, loading and unloading terminals, anchor towers, intermediate (pivoted), towers, and the driving unit(s).

The total capital cost is based on a single cost curve having a tramming rate (X), in metric tons of material moved per day. The curve is valid for a production range of 2,040 to 13,800 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the equipment required for loading, unloading, tramming, and driving units.

BASE CURVE

The capital cost derived from the curve is a combination of the following costs:

Installation labor cost.....	19.0%
Installation materials cost.	4.8%
Equipment cost..............	73.5%
Transportation cost.........	2.7%

The total aerial tramway capital cost is $(Y_C) = 208{,}182.537(X)^{0.385}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_L) = 39{,}554.682(X)^{0.385}$

(S) Installation Materials Cost $(Y_S) = 9{,}992.762(X)^{0.385}$

(E) Purchased Equipment Cost $(Y_E) = 158{,}635.093(X)^{0.385}$

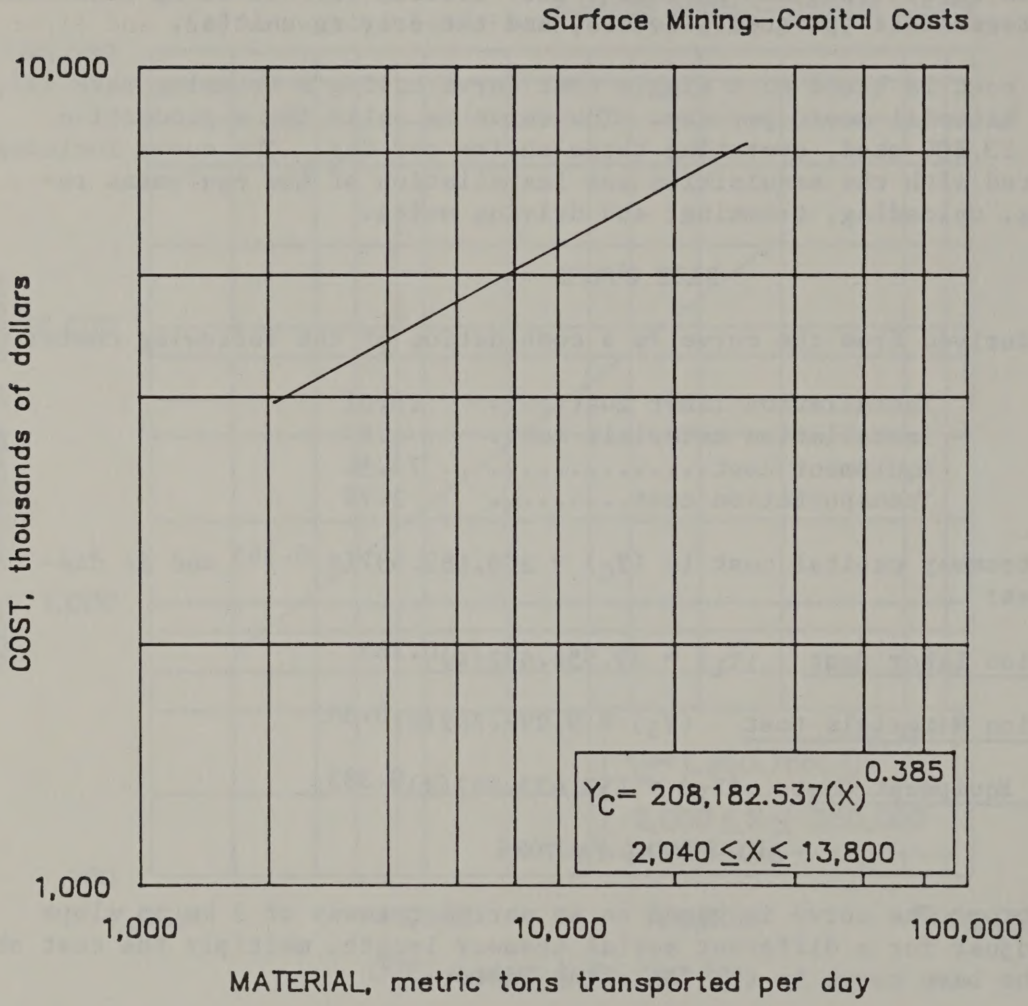
ADJUSTMENT FACTORS

Tramway Length Factor The curve is based on an aerial tramway of 3 km in slope length. To adjust for a different aerial tramway length, multiply the cost obtained from the base curve by the following factor:

Length factor $(Y_L) = 0.233(L)+0.302$
where L = slope length, in kilometers (not to exceed 20 km).

Bulk Density Factor The base curve was calculated with a material bulk density of 1,442.5 km/m^3 (92 lb/ft^3). To adjust the base curve for a different bulk density, multiply the base curve by the following factor:

Bulk density factor $(Y_D) = -0.00003(D)+1.043$
where D = bulk density, in kilograms per cubic meter.



2.2.3.1. Aerial tramway

2.2. SURFACE MINING--CAPITAL COSTS

2.2.3. TRANSPORTATION

2.2.3.2. AIRSTRIP CONSTRUCTION

Airstrip construction cost curves give the cost per meter length of basic utility airstrips varying in width from 10 to 40 m. The airstrip described accommodates light single-engine and small twin-engine airplanes used for personal and business purposes, plus a broader spectrum of small business and air taxi-type twin-engine airplanes. These aircraft include the Cessna 150 series, Piper PA-32-300 Commander Six, Rockwell International 114 Commander, Beech B55 Baron, Cessna 310, and Piper PA-23-250 Aztec.

BASE CURVE

The total capital cost per meter length is based on a single cost curve having an airstrip width (X), in meters. The curve is valid for widths of 10 to 40 m, operating one shift per day. Two surface options are offered, aggregate and asphalt. Not included in this curve are costs for acquisition or clearing of airstrip site, and hauling or rough leveling of fill materials. Both aggregate and bituminous asphalt strips include base preparation (grading and rolling). The aggregate surface includes a base course of 1.9-cm stone, 15 cm deep followed by final grading and rolling. The asphalt surface consists of 31.9-cm stone, 10.2 cm deep, underlying 3.8-cm thick rolled asphalt. No equipment capital costs are incurred. A 5% contingency of total capital cost covers ancillary airstrip facilities such as gas storage and pump, airstrip end and lateral markings, wind direction apparatus, and one T-hangar as needed.

The capital cost derived from the curve is a combination of the following costs:

	Aggregate	Asphalt
Construction labor cost....	20%	16%
Construction supply cost...	80%	84%

The total asphalt airstrip capital cost is $(Y_{C\ ASPHALT}) = 5.686(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ ASPHALT}) = 0.910(X)^{1.000}$

(S) Construction Supply Cost $(Y_{S\ ASPHALT}) = 4.776(X)^{1.000}$

The total aggregate airstrip capital cost is $(Y_{C\ AGGREGATE}) = 3.471(X)^{1.005}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ AGGREGATE}) = 0.694(X)^{1.005}$

(S) Construction Supply Cost $(Y_{S\ AGGREGATE}) = 2.776(X)^{1.005}$

ADJUSTMENT FACTORS

Runway Length Runway length requirement is primarily dependent on anticipated aircraft use, temperature, and elevation. Aircraft type used in the cost curve was previously described. For convenience, an equation was derived to determine length requirement when the elevation of the airstrip is known. The equation is based on maximum temperature of 38° C (100° F). To determine different lengths at different elevations, use the following equation:

Runway length $L = 891.915e^{(0.0005)(E)}$
where L = length of airstrip in, meters,
and E = elevation, in meters.

Runway Width Runway width requirement varies with wingspan of anticipated aircraft using the airstrip. An 18-m wide landing strip will accommodate the aircraft previously described. This width is advised for airstrip predesign costing. Actual width should be used when calculating capital costs of existing airstrips.

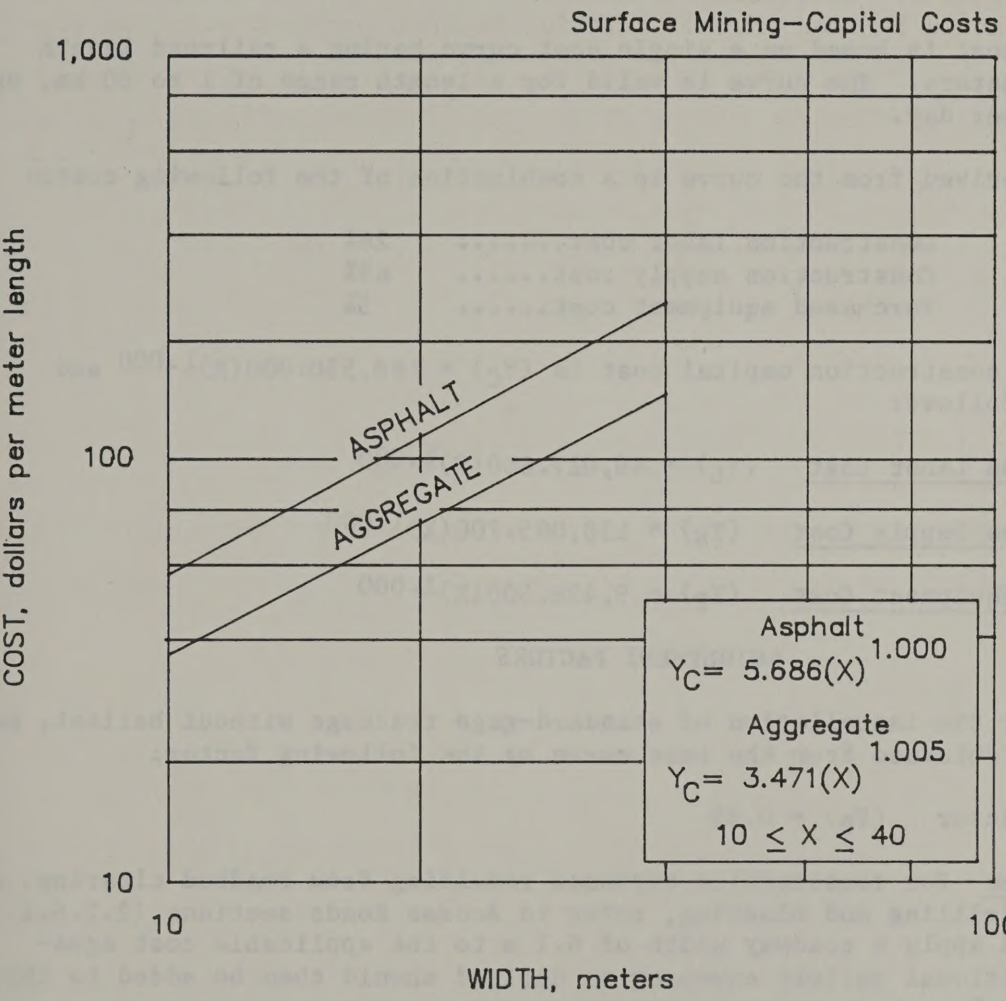
Land Requirements Factor For estimation of land acquisition and clearing requirements for airstrip landing area (includes airstrip pad and lateral-terminal clearances), use the following equation:

Land area requirement in hectares $A = 0.012(L)+1.820$
where L = airstrip length, in meters.

Subcontractor Factor If a subcontractor is used, multiply the curves by the following factors:

Labor factor $(Y_L) = 1.50$

Supply factor $(Y_S) = 1.20$



2.2.3.2. Airstrip construction

2.2. SURFACE MINING--CAPITAL COSTS

2.2.3. TRANSPORTATION

2.2.3.4. RAILROAD CONSTRUCTION

The cost in this section covers the capital expense for laying standard-gage trackage for main lines and spurs. The cost reflects railway installation by a crew that works on a one-shift-per-day schedule; furthermore, the cost is based on trackage that is fully ballasted.

BASE CURVE

The total capital cost is based on a single cost curve having a railroad length (X), in total kilometers. The curve is valid for a length range of 1 to 60 km, operating one shift per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	26%
Construction supply cost......	69%
Purchased equipment cost......	5%

The total railroad construction capital cost is $(Y_C) = 188{,}530.000(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 49{,}017.800(X)^{1.000}$

(S) Construction Supply Cost $(Y_S) = 130{,}085.700(X)^{1.000}$

(E) Purchased Equipment Cost $(Y_E) = 9{,}426.500(X)^{1.000}$

ADJUSTMENT FACTORS

Ballast Factor For the installation of standard-gage trackage without ballast, multiply the cost obtained from the base curve by the following factor:

Ballast factor $(F_B) = 0.85$

Roadbed Construction For construction expenses resulting from roadbed clearing, excavation, and drilling and blasting, refer to Access Roads sections (2.2.6.1.1.-2.2.6.1.5.) and apply a roadway width of 6.1 m to the applicable cost equations; the additional railway expenses so derived should then be added to this section's capital cost.

Equipment Factor When it is necessary to purchase equipment or to have a subcontractor perform the work, multiply the equipment operation value by the following factor in order to obtain the total value of equipment expense for ownership and operation:

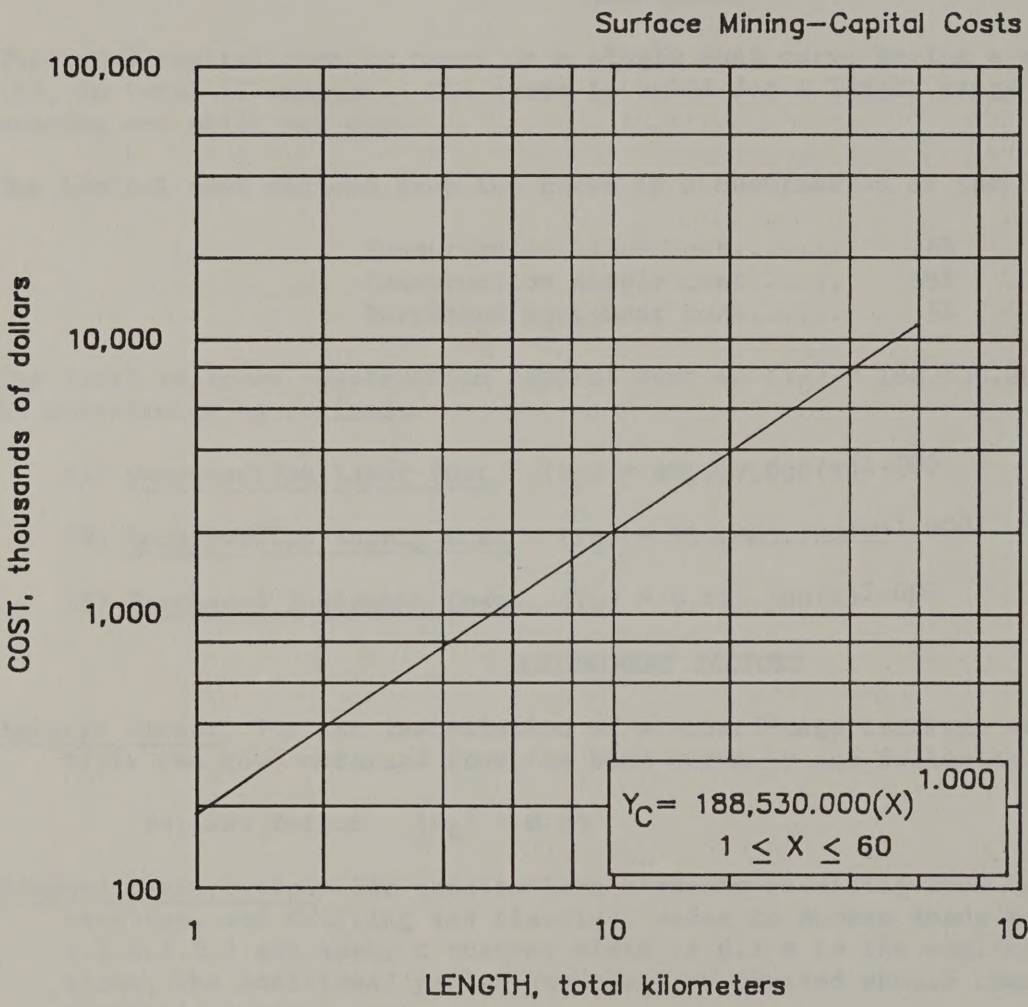
Equipment operation factor $(Y_E) = 1.70$

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(Y_L) = 1.50$

Supply factor $(Y_S) = 1.20$

Equipment operation factor $(Y_E) = 1.20$


Surface Mining—Capital Costs

2.2.3.4. Railroad construction

2.2. SURFACE MINING--CAPITAL COSTS

2.2.3. TRANSPORTATION

2.2.3.5. LONG DISTANCE SURFACE CONVEYOR

The cost curve shown is for the acquisition and erection of a long-distance surface conveyor. The conveyor is a single-flight belt conveyor made with high-strength steel belting. The conveyor is designed for a 10° slope and 1-km distance. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher capital costs are not included in this cost but are covered in separate sections.

BASE CURVE

The total cost is based on a single cost curve having a daily production rate (X), in metric tons material transported per day. The curve is valid for production rates of 15,000 to 150,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, installation of the belt, idlers, motors, channel, and frame, and site preparation.

The long-distance surface conveyor capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	31%
Construction supply cost......	5%
Purchased equipment cost......	64%

A typical breakdown of a long distance surface conveyor major cost components is:

Conveyor belt.......................	36%
Idler assembly units................	44%
Motors, drive trains, belt cleaners, and other mechanical items.........	20%

The total long distance surface conveyor capital cost is $(Y_C) = 81{,}292.281(X)^{0.309}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 25{,}200.607(X)^{0.309}$

(S) Construction Supply Cost $(Y_S) = 4{,}064.614(X)^{0.309}$

(E) Purchased Equipment Cost $(Y_E) = 52{,}027.060(X)^{0.309}$

ADJUSTMENT FACTORS

Belt Life The conveyor belt, 36% of equipment cost, has an average wear life of 8 to 10 yr of use, based on three shifts per day, 350 operating days per year, and depending on the abrasiveness of the material. The total replacement of the belt is standard procedure after excessive wear.

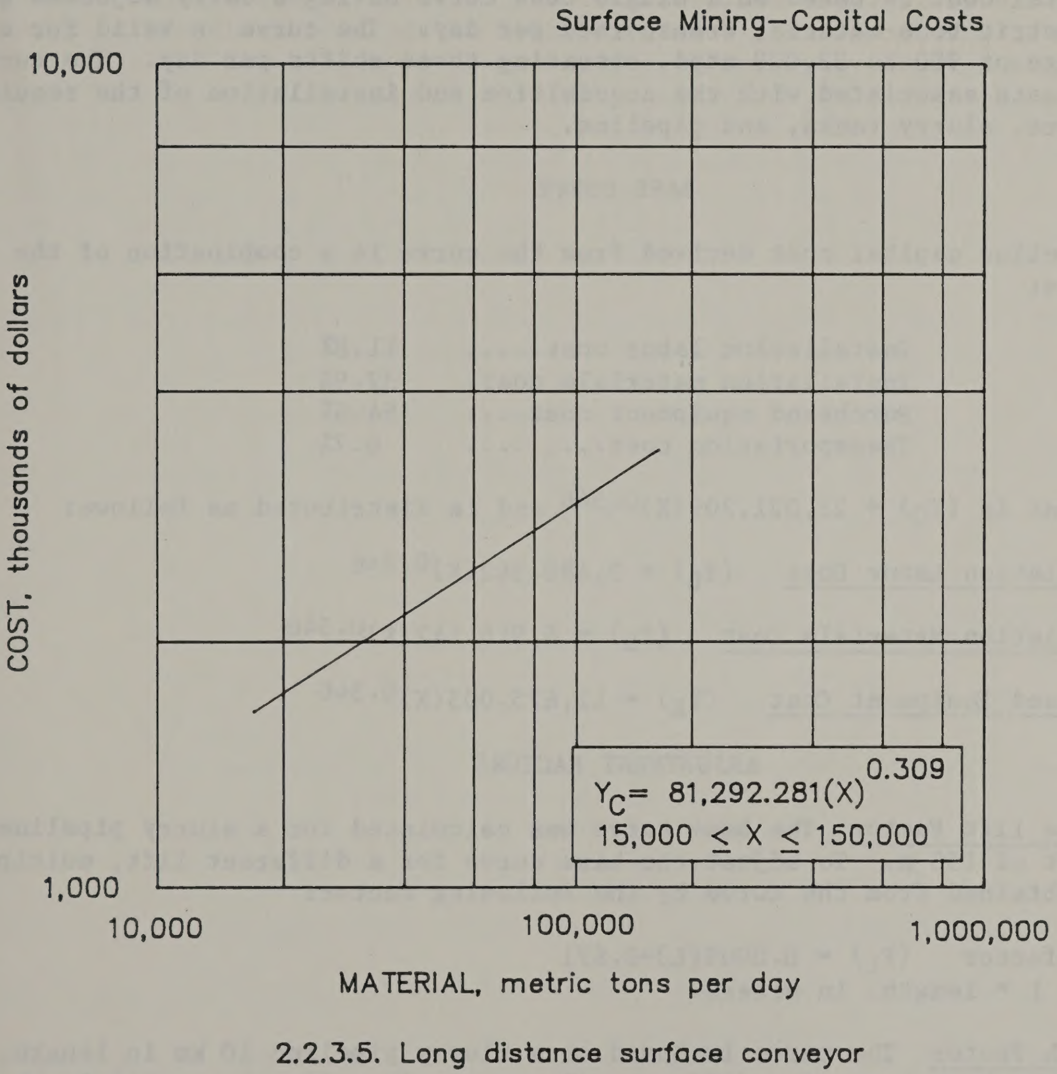
Conveyor Length and Slope Factor The conveyor is 1-km long and has a 10° slope.

For other lengths and slopes, multiply the cost obtained from the base curve by the following factor:

Conveyor length and slope factor $(F_L) = [0.917+0.00940(S)][L/1]$
where L = length, in kilometers,
and S = slope, in degrees, between 0° and 15°.

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).

Stacker-Tripper Factor If the material is conveyed to a processing plant or other end point such as a port facility, the capital cost for unloading from the conveyor is included in those sections. If the material is waste rock, then the cost for a tripper or stacker should be added to the estimated capital cost. Costs for these items vary greatly but can range from $600,000 for a stacker or tripper that handles 15,000 mtpd waste material to $5,000,000 for a stacker or tripper that handles 150,000 mtpd of waste rock.



2.2.3.5. Long distance surface conveyor

2.2. SURFACE MINING--CAPITAL COSTS

2.2.3. TRANSPORTATION

2.2.3.8. SLURRY PIPELINE

The capital cost curve for the slurry pipeline is for the acquisition and installation of equipment for pumping a slurry 10 km at a lift of 150 m with a specific gravity of the solids of 4.3. The slurry pipeline circuit includes slurry storage tanks, booster and high-pressure slurry pumps, and the pipeline.

The total capital cost is based on a single cost curve having a daily adjusted feed rate (X), in metric tons material transported per day. The curve is valid for a production range of 900 to 32,000 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the required pumps, agitators, slurry tanks, and pipeline.

BASE CURVE

The slurry pipeline capital cost derived from the curve is a combination of the following costs:

Installation labor cost.....	11.8%
Installation materials cost.	32.9%
Purchased equipment cost....	54.6%
Transportation cost.........	0.7%

The capital cost is $(Y_C) = 21,021.709(X)^{0.546}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_L) = 2,480.562(X)^{0.546}$

(S) Installation Materials Cost $(Y_S) = 6,916.142(X)^{0.546}$

(E) Purchased Equipment Cost $(Y_E) = 11,625.005(X)^{0.546}$

ADJUSTMENT FACTORS

Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust the base curve for a different lift, multiply the cost obtained from the curve by the following factor:

Lift factor $(F_L) = 0.0009(L)+0.871$
where L = length, in meters.

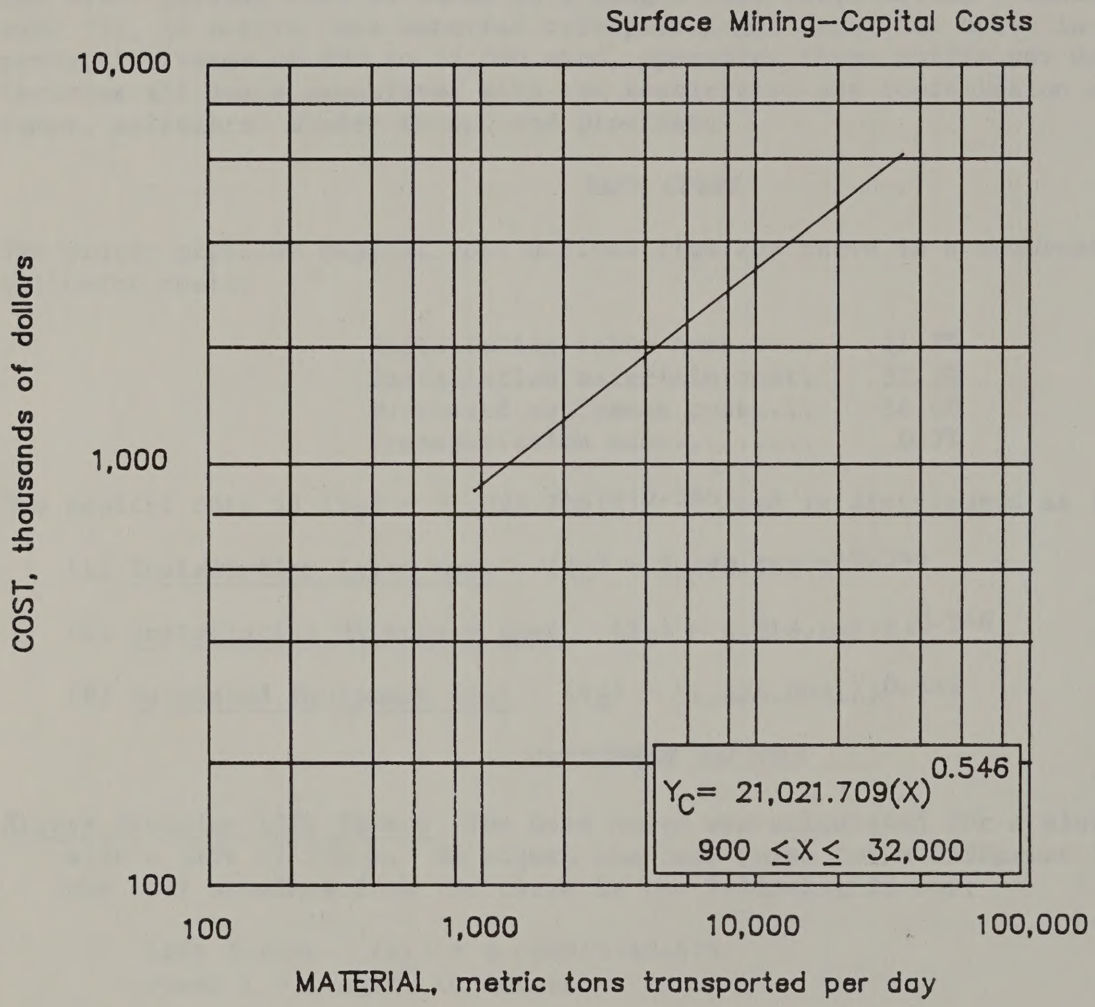
Pipeline Length Factor The curve is based on a slurry pipeline 10 km in length. To adjust the base curve for different slurry pipeline lengths, multiply the cost obtained from the curve by the following factor:

Length factor $(F_K) = 0.026(K)+0.741$
where K = length, in kilometers.

An estimate of average pipeline length can be made from table A-3 in the appendix.

Specific Gravity Factor The base curve was calculated for a slurry pipeline pumping solids with specific gravity of 4.3. To adjust the curve for a different specific gravity, multiply the cost obtained from the curve by the following factor (an estimate of average specific gravity can be made from Table A-3 in the appendix):

Specific gravity factor $(F_S) = 0.023(S)+0.903$
where S = new specific gravity.



2.2.3.8. Slurry pipeline

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.1. COMMUNICATIONS SYSTEM

The communications system curve is based on installed costs for a radio network and surface telephone service. The radio system contains mobile and base units with one or more repeaters, depending on the size of the mine and the number of frequencies used, as well as portable radios. Telephone service costs are based on a complete telephone system, with installation by an outside agency.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted mine production rate (X), in metric tons ore and waste per day. The curve is valid for a production range of 1,000 to 400,000 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of telephones and telephone lines, mobile and base radio units, repeaters and repeater towers, control consoles, and portable radios.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	9%
Purchased equipment cost.......	91%

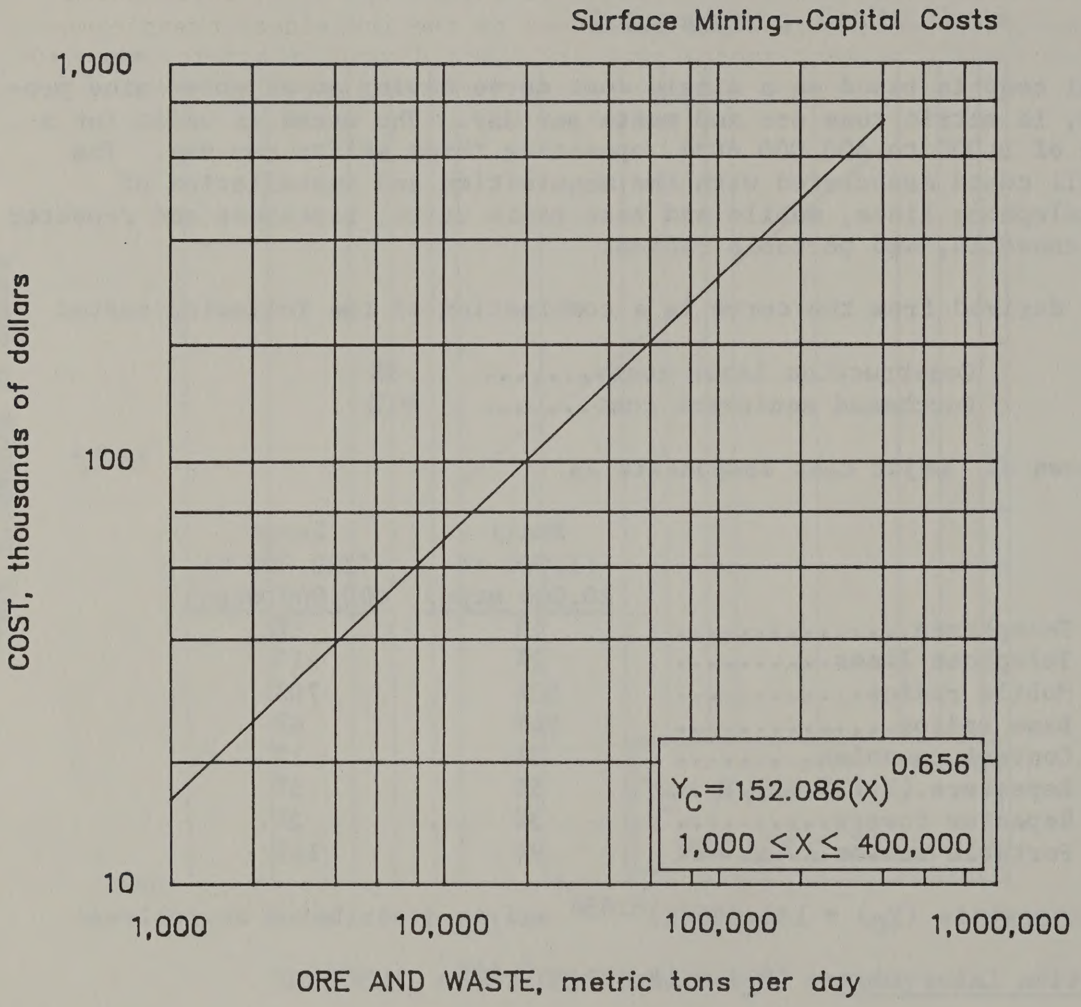
A typical breakdown of major cost components is

	Small (1,000 to 20,000 mtpd)	Large (200,000 to 400,000 mtpd)
Telephones...............	1%	1%
Telephone lines..........	2%	1%
Mobile radios............	53%	70%
Base radios..............	24%	6%
Control consoles.........	3%	1%
Repeaters................	5%	5%
Repeater towers..........	3%	2%
Portable radios..........	9%	14%

The total capital cost is $(Y_C) = 152.086(X)^{0.656}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 13.687(X)^{0.656}$

(E) Purchased Equipment Cost $(Y_E) = 138.398(X)^{0.656}$



2.2.4.1. Communications system

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.2. ELECTRICAL SYSTEM

The cost shown is for the acquisition and installation of the primary skid-mount transformers dedicated to individual units of equipment, the necessary trailing cables, and ancillary pole-mount transformers (for mine shop, lighting, and/or pumping). The cost curves are based on total metric tons of ore and waste handled per day by an electric shovel-truck mining method or by a nonelectric shovel-truck mining method on a three-shift basis. All power is 25,000 V, 60 Hz, three-phase electricity to the transformer sites. To get power to the individual transformer sites, distribution lines, primary substations (if power demand is greater than 10 MW), and primary transmission lines (where location does not have close proximity to existing 115- or 230-kV lines for primary substation feed) must be accounted for (see section 2.2.6.2. Main Power Lines).

BASE CURVE

The total capital cost is based on two single cost curves having adjusted production rates (X), in metric tons ore and waste per day. The curves are valid for a production range of 1,000 to 500,000 mtpd, operating three shifts per day. The curves include all costs associated with the acquisition and installation of portable skid-mount transformers, pole-mount transformers, and trailing cables.

The capital cost derived from the curve is a combination of the following costs:

	Nonelectric shovel (1,000 to 10,000 mtpd)	Electric shovel (10,000 to 500,000 mtpd)
Installation labor cost[1]	47%	10%
Purchased equipment cost[2]	53%	89%
Freight cost	-	1%

A typical breakdown of major cost components is

	Nonelectric shovel (1,000 to 10,000 mtpd)	Electric shovel (10,000 to 500,000 mtpd)
Skid-mounted transformers	-	53%
Pole-mounted transformers	100%	2%
Trailing cable	-	45%

[1] Installation cost is composed of 90% labor and 10% equipment operation for nonelectric shovel mines and 97% labor and 3% equipment operation for electric shovel mines. The equipment operation cost is composed of 41% repair-maintenance labor, 34% repair parts, 23% fuel and lubrication, and 2% tires.

[2] Equipment costs include construction materials.

The total capital cost for nonelectric shovel mines is $(Y_C) = 146.854(X)^{0.412}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ NONELECT}) = 69.021(X)^{0.412}$

(E) Purchased Equipment Cost $(Y_{E\ NONELECT}) = 77.832(X)^{0.412}$

The total capital cost for electric shovel mines is $(Y_C) = 245.054(X)^{0.660}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ ELECT}) = 24.505(X)^{0.660}$

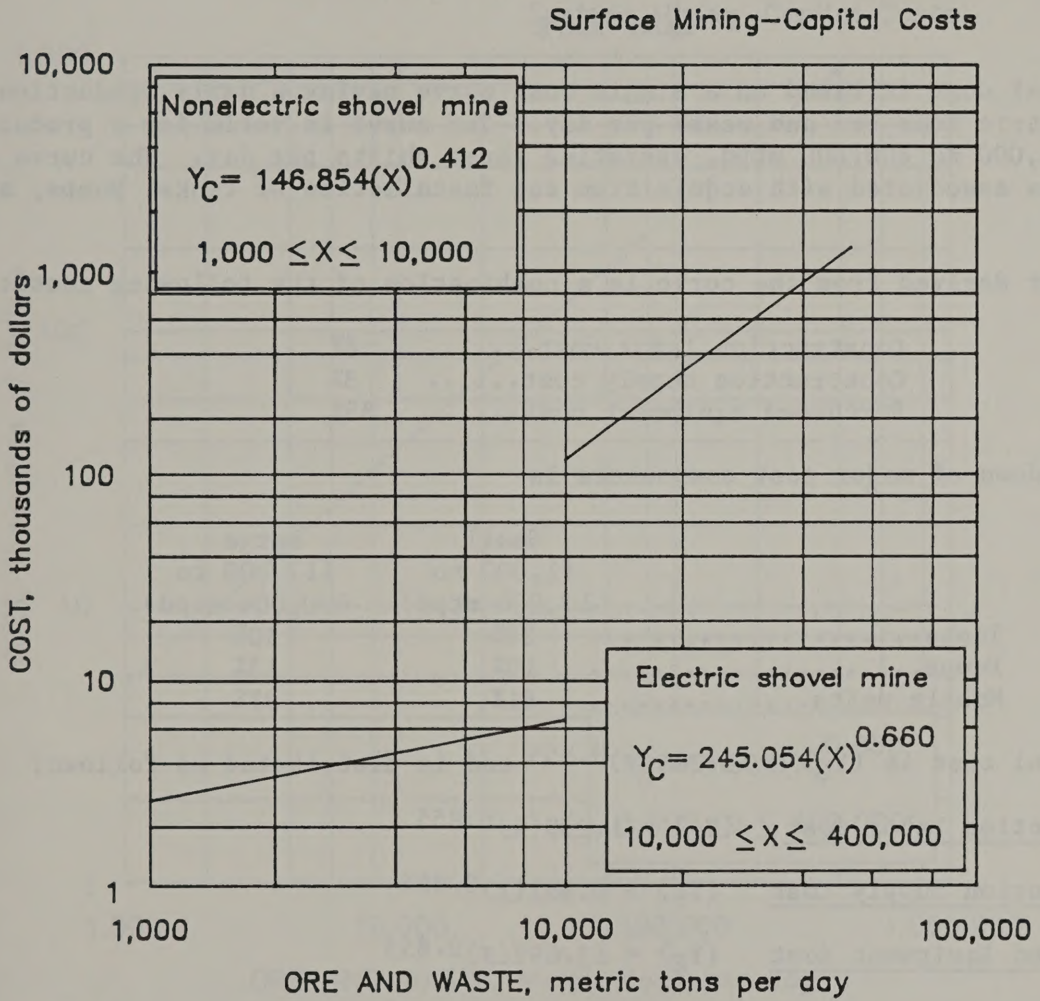
(E) Purchased Equipment Cost $(Y_{E\ ELECT}) = 220.548(X)^{0.660}$

ADJUSTMENT FACTORS

Self-Generated Power Electric Shovel Operations If the mine uses self-generated power from a central location, then the cost of portable power (section 2.2.4.6.) must be added to the cost from this section (power consumption ranges from 67 kW at 10,000 mtpd to 4,800 kW at 500,000 mtpd).

Self-Generated Power Nonelectric Shovel Operations If the mine uses self-generated power from a central location, then the cost of portable power (section 2.2.4.6.) must be added to the cost from this section (power consumption ranges from 1.9 kW at 1,000 mtpd to 20 kW at 10,000 mtpd).

Portable Power Nonelectric Shovel Operations If the mine uses portable, self-contained, light-generator or pump-generator units in the pit, then the portable power section (section 2.2.4.6.) should be used in place of this section for mine plant only (power consumption ranges from 0.64 kW at 1,000 mtpd to 6.7 kW at 10,000 mtpd).



2.2.4.2. Electrical system

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.3. FUELING SYSTEM

This curve is representative of the cost of fueling systems handling diesel fuel, gasoline, lubricants, coolants, and waste oil for truck haulage systems. It is based on one stationary fueling point and one or more mobile units. Any building required for fueling facilities is covered in section 2.2.4.9. (Surface Buildings). Tanks are sized on the basis of a weekly refilling.

BASE CURVE

The total capital cost is based on a single cost curve having a daily production rate (X), in metric tons ore and waste per day. The curve is valid for a production range of 1,000 to 400,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of tanks, pumps, and mobile units.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	8%
Construction supply cost......	3%
Purchased equipment cost......	89%

A typical breakdown of major cost components is

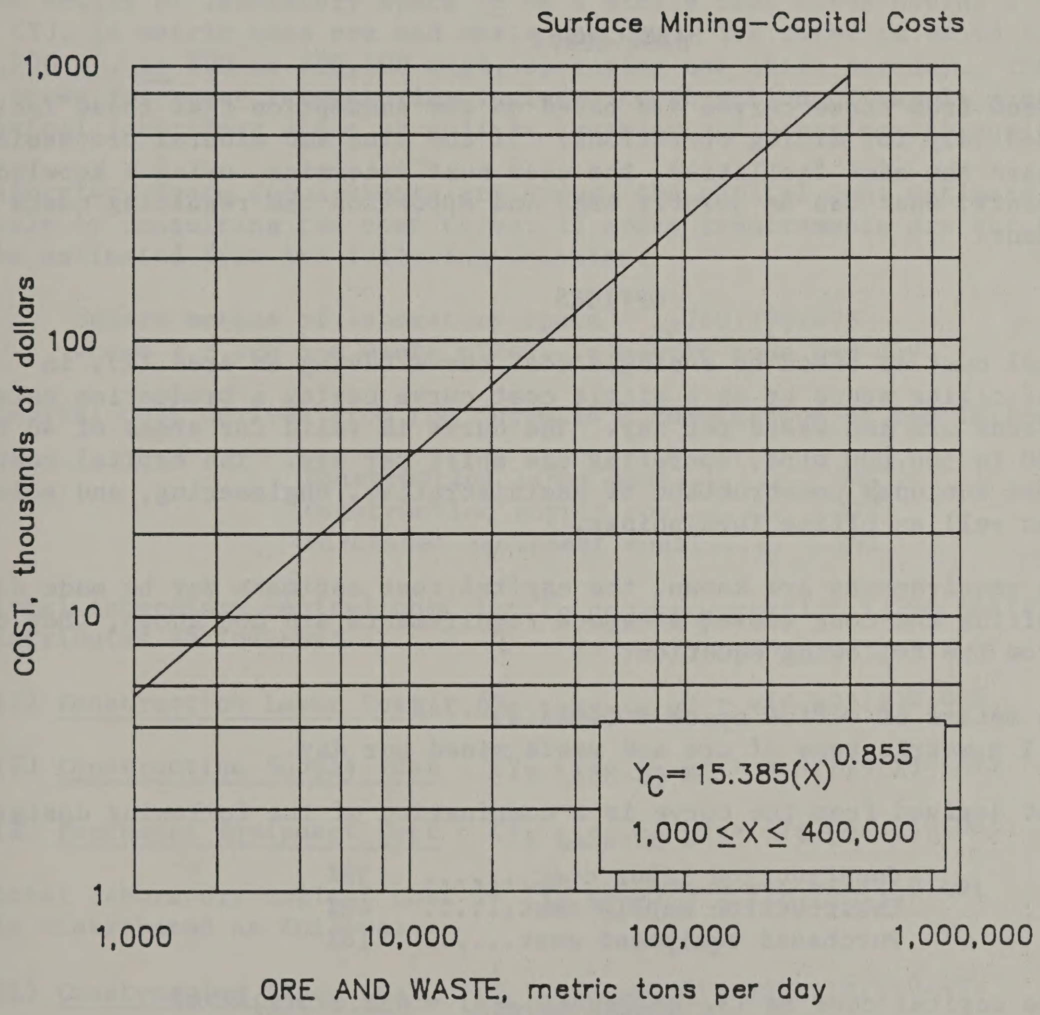
	Small (1,000 to 17,000 mtpd)	Large (17,000 to 400,000 mtpd)
Tanks.....................	29%	50%
Pumps.....................	10%	13%
Mobile units.............	61%	37%

The total capital cost is $(Y_C) = 15.385(X)^{0.855}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1.230(X)^{0.855}$

(S) Construction Supply Cost $(Y_S) = 0.462(X)^{0.855}$

(E) Purchased Equipment Cost $(Y_E) = 13.692(X)^{0.855}$



2.2.4.3. Fueling system

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.5. OFFICES AND LABORATORIES

The cost curves for offices and laboratories include construction of general offices, engineering and safety offices, and laboratories, including furnishings as well as all necessary assay equipment. Building costs are based on masonry two-story buildings. In this section, office and laboratory capital costs are presented separately.

BASE CURVE

The costs obtained from these curves are based on the assumption that these facilities will be used only for mining operations. If the mine and mineral processing plant are to share the same facilities, the user must determine, using a knowledge of the requirements, what can be jointly used and apportion the resulting costs to the mine and plant.

OFFICES

The total capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons ore and waste per day. The curve is valid for areas of 40 to 9,600 m^2, or 800 to 500,000 mtpd, operating one shift per day. The capital cost curve for offices includes construction of administrative, engineering, and safety office space, as well as office furnishings.

If office space requirements are known, the capital cost estimate may be made directly by consulting the cost curve; if space requirements are not known, they can be estimated from the following equation:

Square meters of office space = $0.511(T)^{0.746}$
where T = metric tons of ore and waste mined per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	38%
Construction supply cost......	48%
Purchased equipment cost......	14%

The total office capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 651.940(X)^{0.968}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{OFFICES\text{-}SQ\ M}}) = 247.737(X)^{0.968}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{OFFICES\text{-}SQ\ M}}) = 312.931(X)^{0.968}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{OFFICES\text{-}SQ\ M}}) = 91.272(X)^{0.968}$

The total office capital cost is $(Y_{C\ MTPD}) = 336.202(T)^{0.723}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ OFFICES\text{-}MTPD}) = 127.756(T)^{0.723}$

(S) Construction Supply Cost $(Y_{S\ OFFICES\text{-}MTPD}) = 161.376(T)^{0.723}$

(E) Purchased Equipment Cost $(Y_{E\ OFFICES\text{-}MTPD}) = 47.068(T)^{0.723}$

LABORATORIES

The total capital cost is based on a single cost curve having an area (X), in square meters of laboratory space or on a single cost curve having a production rate (T), in metric tons ore and waste per day. The curve is valid for areas of 40 to 1,200 m^2, or 800 to 400,000 mtpd, operating one shift per day. The capital cost curve for assay laboratories includes construction of sample preparation and analytical laboratory space as well as crushing and assaying lab equipment.

If laboratory space requirements are known, the capital cost estimate may be made directly by consulting the cost curve; if space requirements are not known, they can be estimated from the following equation:

Square meters of laboratory space = 1.760(T)0.475
where T = ore and waste mined, in metric tons per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	34%
Construction supply cost......	37%
Purchased equipment cost......	29%

The total laboratory capital cost is $(Y_{C\ SQUARE\ METERS}) = 1{,}296.566(X)^{0.885}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS\text{-}SQ\ M}) = 440.832(X)^{0.885}$

(S) Construction Supply Cost $(Y_{S\ LABS\text{-}SQ\ M}) = 479.729(X)^{0.885}$

(E) Purchased Equipment Cost $(Y_{E\ LABS\text{-}SQ\ M}) = 376.004(X)^{0.885}$

The total laboratory capital cost is $(Y_{C\ MTPD}) = 2{,}118.290(T)^{0.421}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS\text{-}MTPD}) = 720.218(T)^{0.421}$

(S) Construction Supply Cost $(Y_{S\ LABS\text{-}MTPD}) = 783.767(T)^{0.421}$

(E) Purchased Equipment Cost $(Y_{E\ LABS\text{-}MTPD}) = 614.304(T)^{0.421}$

ADJUSTMENT FACTORS

Shift Adjustment The square meters of laboratory space required is based on a three-shift operation. To adjust the capital cost for a different number of daily operating shifts, multiply the actual daily tonnage by the ratio of the base number of shifts (3) divided by the number of desired shifts. Then, use this modified production rate in place of actual daily tonnage in the above area versus tonnage equation to obtain the adjusted area. Then, enter the adjusted area in the cost equation to obtain the adjusted capital cost. The square meters of office space is not contingent on the number of shifts and requires no adjustment. If the number of square meters of laboratory space is known, do not use this adjustment factor.

Temperature Factor The buildings are based on temperature requirements for the Denver, CO, area. For milder areas multiply the costs obtained from the base curve by the following factor:

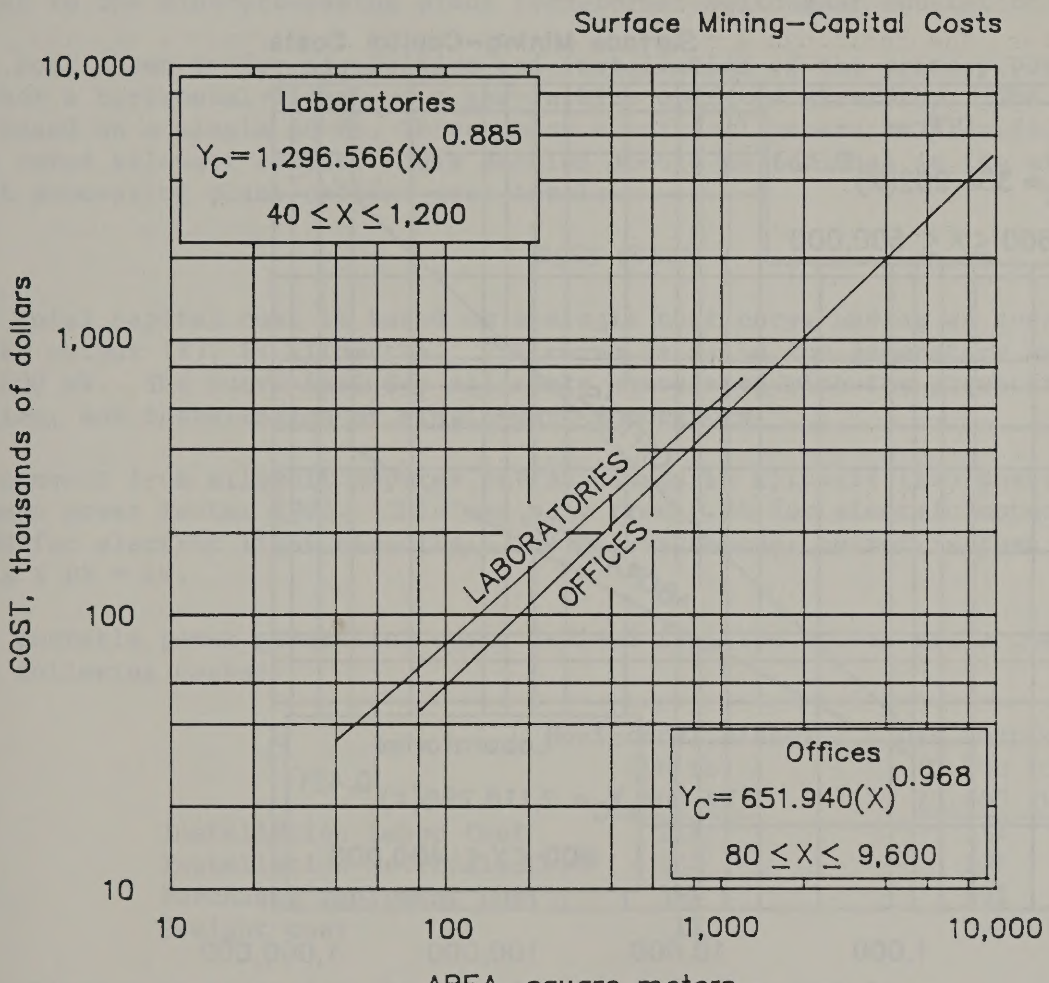
Temperature factor $(F_{T\ MILD}) = 0.94$

For more severe areas multiply the costs obtained from the base curve by the following factor:

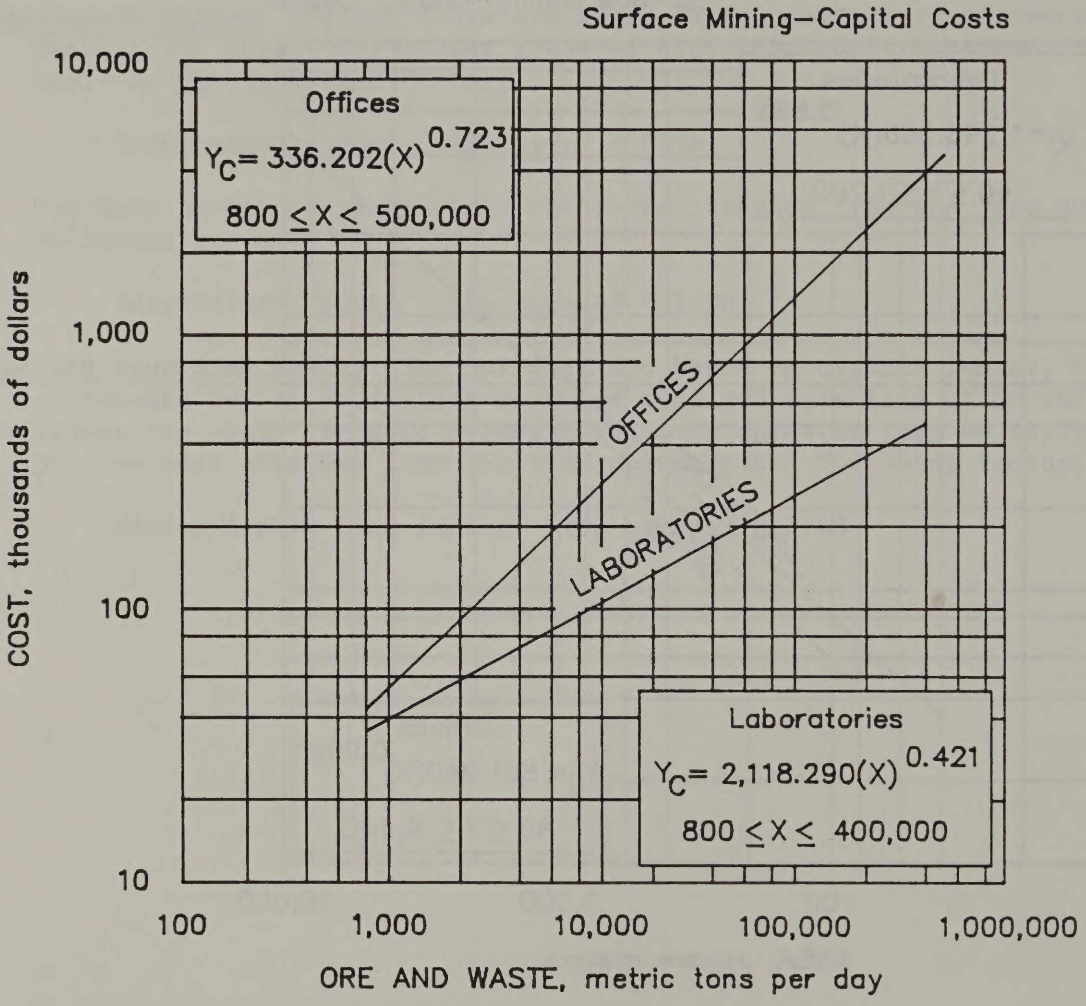
Temperature factor $(F_{T\ SEVERE}) = 1.08$

Wind and Snow Load Factor The building are based on typical Denver, CO, area requirements for an equivalent combined wind and snow load of 20 lb/ft^2. To adjust the costs for more severe conditions (greater than 40 lb/ft^2), multiply the cost obtained from the base curve by the following factor:

Wind and snow load factor $(F_{S\ SEVERE}) = 1.03$



2.2.4.5.a Offices and laboratories



2.2.4.5.b Offices and laboratories

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.6. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 3.2.4.6. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. No adjustments are necessary for the mine (sections 2.2.4.2., 4.2.5.3.) or mineral processing plant (section 6.1.8.4, IC 9143) electrical system because output power matches the power input to the mine-processing plant transformer-switchgear substations.

The cost shown is for acquisition and installation of the primary power source, either a horizontal-diesel or a gas-turbine operated generator. The cost curve is based on a single 60-Hz, three-phase electrical generator providing all power at the rated kilowatt output. This section should be included in the mine and/or mineral processing plant capital cost totals.

BASE CURVE

The total capital cost is based on a single cost curve having an average continuous power output (X), in kilowatts. The curve is valid for generators between 18 to 23,600 kW. The curve includes all costs associated with the acquisition, transportation, and installation of single-unit generators.

To convert from kilovolt amperes (kV•A) demand to kilowatt (kW) power output, estimate power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt power output is then determined by kV•A X PF = kW.

The portable power generation costs derived from the curves are a combination of the following costs::

	Horizontal diesel (18 to 2,900 kW)	Gas turbine (2,900 to 23,600 kW)
Installation Labor Cost	21%	21%
Installation Materials Cost	20%	20%
Purchased Equipment Cost	58%	59%
Freight cost	1%	-

Installation is assumed to be half labor and half materials.

The total diesel-powered portable power generation capital cost is $(Y_{C\ DIESEL}) = 797.574(X)^{0.876}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ DIESEL}) = 167.491(X)^{0.876}$

(S) Installation Materials Cost $(Y_{S\ DIESEL}) = 159.514(X)^{0.876}$

(E) Purchased Equipment Cost $(Y_{E\ DIESEL}) = 470.568(X)^{0.876}$

The total turbine-powered portable power generation capital cost is $(Y_{C\ TURBINE}) = 2{,}251.219(X)^{0.872}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ TURBINE}) = 472.756(X)^{0.872}$

(S) Installation Materials Cost $(Y_{S\ TURBINE}) = 450.244(X)^{0.872}$

(E) Purchased Equipment Cost $(Y_{E\ TURBINE}) = 1328.219(X)^{0.872}$

Power Output Determination For surface mine power output (kW), see Electrical System (section 2.2.4.2.). For underground mine and mineral processing plant power demand (kV•A), see Electrical System (sections 4.2.5.3. and 6.1.8.4. (IC 9143)).

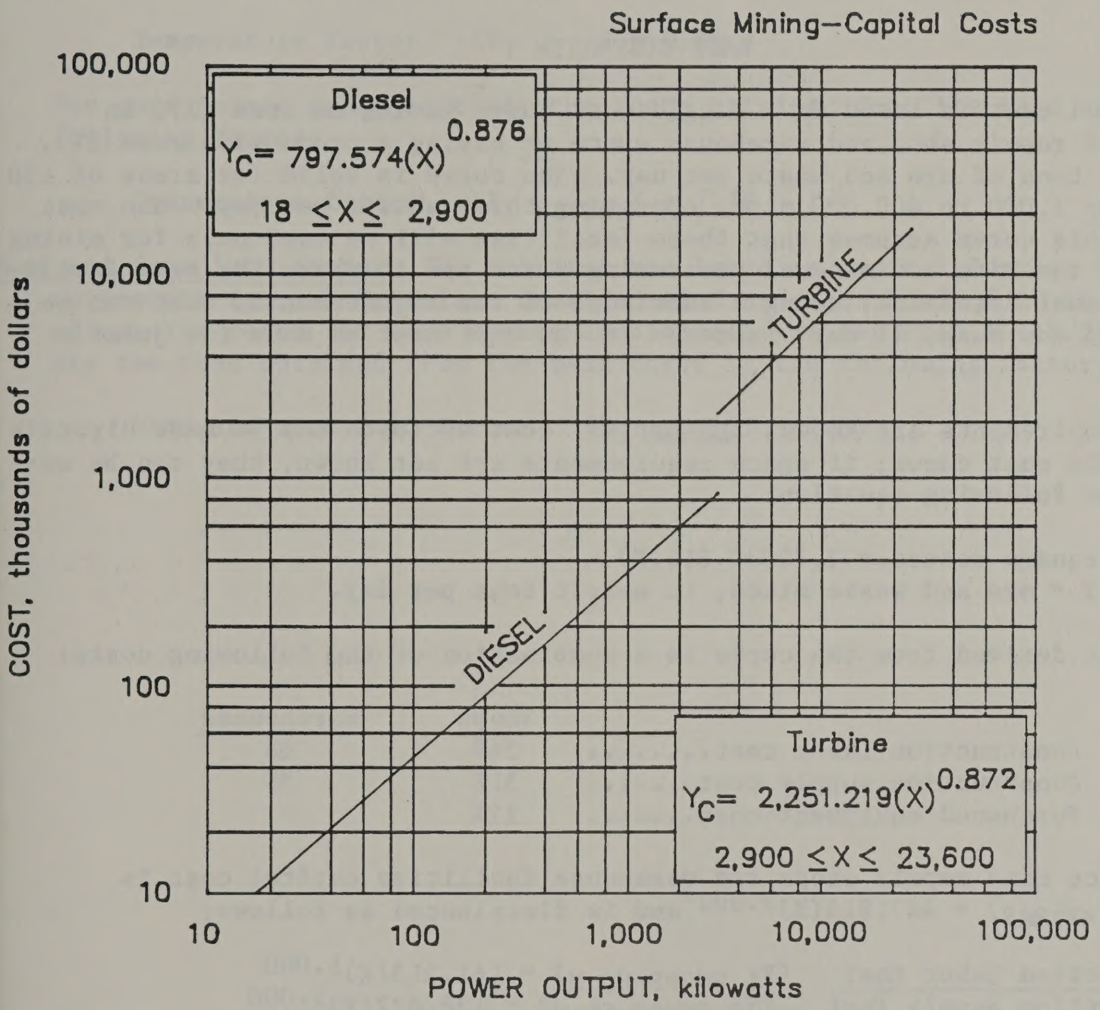
ADJUSTMENT FACTORS

Power Rate If power is to be supplied by more than one unit, the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curve. After the unit cost has been calculated, the cost must be multiplied by the total number of units used.

Power Source If geography or economics necessitate multiple power sites to support mines and mineral processing plants, portable power cost should be estimated separately for each site using this section.

Shift Adjustment Adjustment for the number of operating shifts is implicit in the choice of the average continuous power output.

Economic Life The normal economic life for generators is 25,000 hr for units rated at 1,100-kW output or greater and ranges from 11,000 to 17,500 hr for units rated at less than 1,100-kW output. If the units are operated at standby rates, roughly 10 percent over capacity, the economic life would decrease by 50%. If high-sulfur fuels are used, the economic life would be decreased by 25%.



2.2.4.6. Portable power generation

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.7. REPAIR SHOPS AND WAREHOUSES

Repair shops and warehouses include buildings, equipment, floors, foundations, and aprons. Building costs are based on steel superstructure and concrete block exterior walls. Costs include all applicable equipment, and cover all types of surface mining operations and haulage. The buildings are based on weather requirements for the Denver, CO, area.

BASE CURVE

The total capital cost is based on a single cost curve having an area (X), in square meters of repair shop and warehouse space or having a production rate (T), in total metric tons of ore and waste per day. The curve is valid for areas of 150 to 10,000 m^2, or 1,000 to 400,000 mtpd, operating three shifts per day. The cost obtained from this curve assumes that these facilities will be used only for mining operations. If the mine and mineral processing plant are to share the same facilities, the user must determine, using a knowledge of the requirements, what can be jointly used and how much, if any, increase to the cost must be made for joint usage.

If the space requirements are known, the capital cost estimate may be made directly by consulting the cost curve; if space requirements are not known, they can be estimated from the following equation:

Total square meters = 2,703+0.016(T)
where T = ore and waste mined, in metric tons per day.

The capital cost derived from the curve is a combination of the following costs:

	Shops	Warehouses
Construction labor cost........	36%	6%
Construction supply cost.......	31%	5%
Purchased equipment cost.......	22%	-

The total surface mine repair shops and warehouse facilities capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 447.814(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SHOPS-SQ\ M}}) = 161.213(X)^{1.000}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SHOPS-SQ\ M}}) = 138.822(X)^{1.000}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SHOPS-SQ\ M}}) = 98.519(X)^{1.000}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{WAREHOUSES-SQ\ M}}) = 26.869(X)^{1.000}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{WAREHOUSES-SQ\ M}}) = 22.391(X)^{1.000}$

The total surface mine repair shops and warehouse facilities capital cost is: $(Y_{C\ \mathrm{MTPD}}) = 31{,}103.546(T)^{0.373}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SHOPS\text{-}MTPD}}) = 11{,}197.277(T)^{0.373}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SHOPS\text{-}MTPD}}) = 9{,}642.099(T)^{0.373}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SHOPS\text{-}MTPD}}) = 6{,}842.780(T)^{0.373}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{WAREHOUSES\text{-}MTPD}}) = 1{,}866.213(T)^{0.373}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{WAREHOUSES\text{-}MTPD}}) = 1{,}555.177(T)^{0.373}$

ADJUSTMENT FACTORS

Temperature Factor The buildings are based on temperature requirements for the Denver, CO, area. For milder areas multiply the costs obtained from the base curve by the following factor:

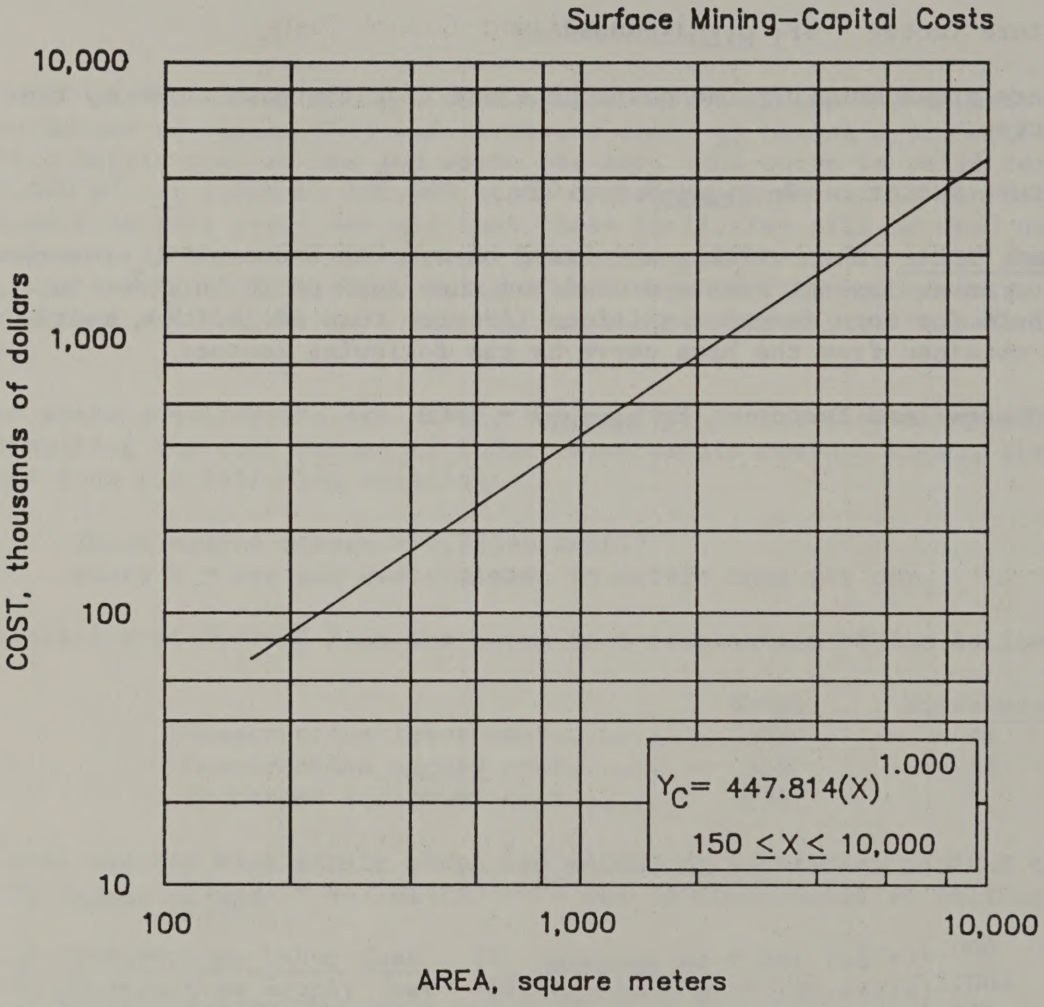
Temperature factor $(F_{T\ \mathrm{MILD}}) = 0.94$

For more severe areas multiply the costs obtained from the base curve by the following factor:

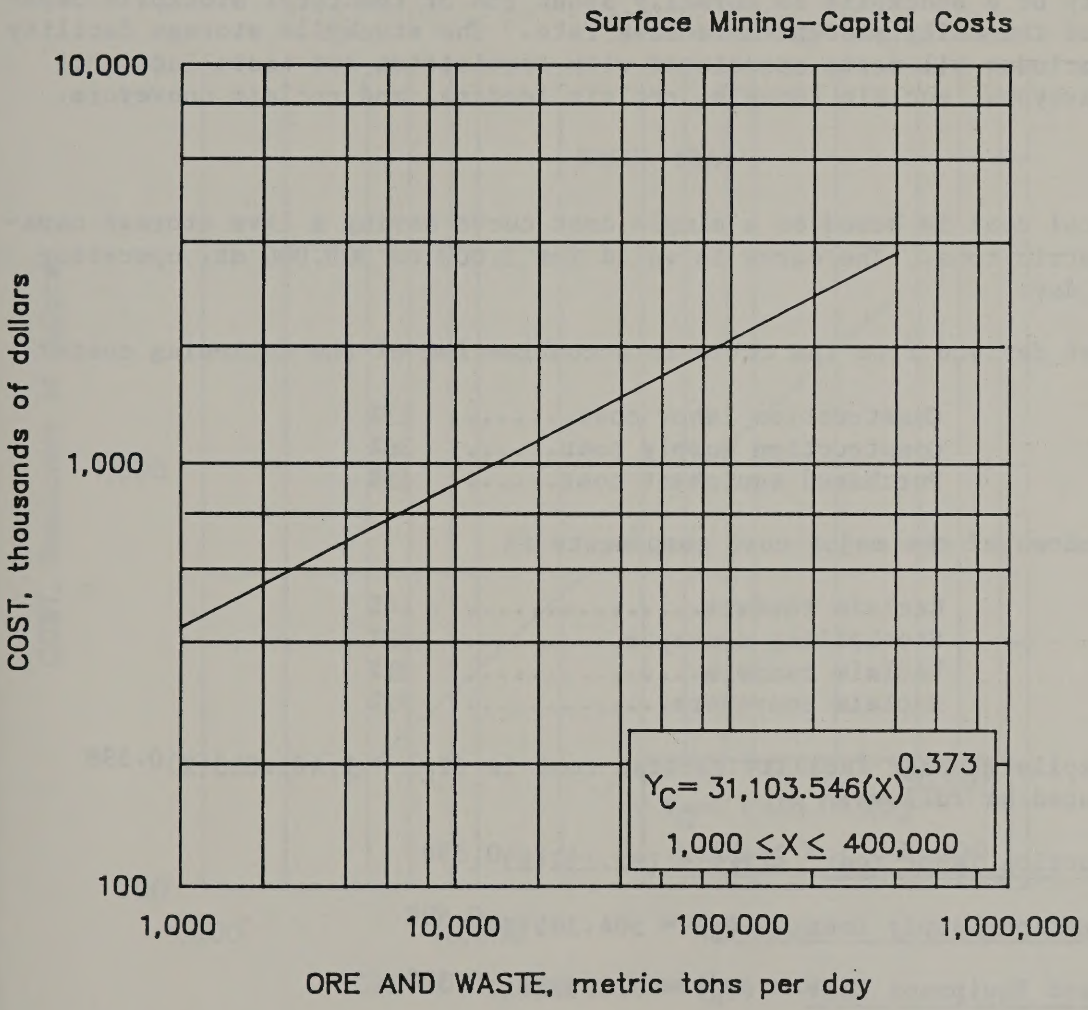
Temperature factor $(F_{T\ \mathrm{SEVERE}}) = 1.08$

Wind and Snow Load Factor The building are based on typical Denver, CO, area requirements for an equivalent combined wind and snow load of 20 lb/ft^2. To adjust the costs for more severe conditions (greater than 40 lb/ft^2), multiply the cost obtained from the base curve by the following factor:

Wind and snow load factor $(F_{S\ \mathrm{SEVERE}}) = 1.03$



2.2.4.7.a Repair shops and warehouses



Surface Mining—Capital Costs

2.2.4.7.b Repair shops and warehouses

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.8. STOCKPILE STORAGE FACILITIES

A stockpile storage facility provides sufficient storage capacity for a material until it can be further processed. A storage facility may also provide adequate reserve material to dampen surges in the material supply. Examples of materials stockpiled are smelter flux, coal, and coarse ore. For this base curve, capital cost is correlated to the live storage capacity of the stockpile facility. Live storage capacity of a stockpile is normally about 25% of the total stockpile capacity and 150% of the daily stockpile reclaim rate. The stockpile storage facility capital cost includes all costs associated with acquisition and installation of stockpiling conveyors, reclaim tunnels, reclaim feeders, and reclaim conveyors.

BASE CURVE

The total capital cost is based on a single cost curve having a live storage capacity (X), in metric tons. The curve is valid for 3,000 to 300,000 mt, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	13%
Construction supply cost......	36%
Purchased equipment cost......	51%

A typical breakdown of the major cost components is

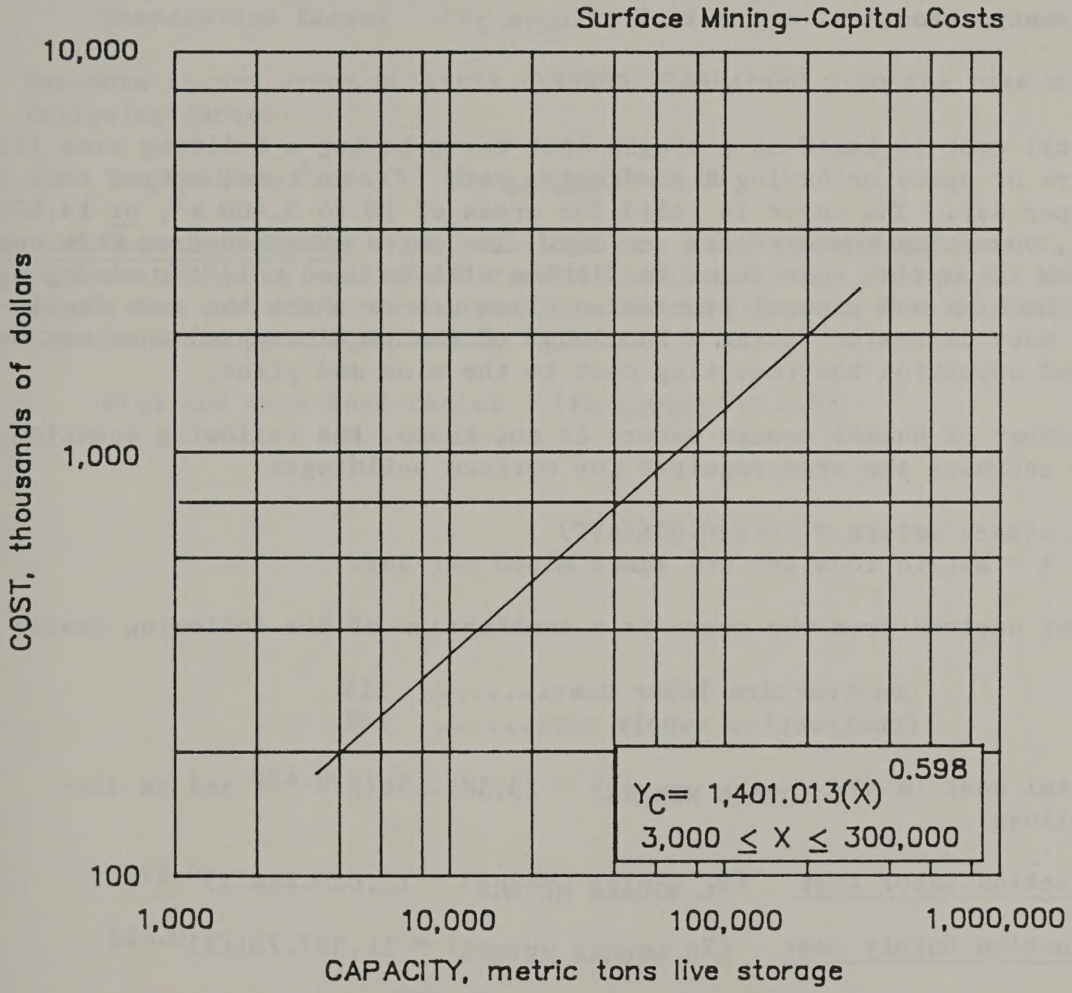
Reclaim feeders..............	14%
Stockpiling conveyor..........	23%
Reclaim tunnels...............	31%
Reclaim conveyors............	32%

The total stockpile storage facility capital cost is $(Y_C) = 1{,}401.013(X)^{0.598}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 182.132(X)^{0.598}$

(S) Construction Supply Cost $(Y_S) = 504.365(X)^{0.598}$

(E) Purchased Equipment Cost $(Y_E) = 714.516(X)^{0.598}$



2.2.4.8. Stockpile storage facilities

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.9. SURFACE BUILDINGS

The cost curve for surface buildings covers the general support facilities for the mining operation, including change house, powder magazine, tool sheds, guard houses, fencing, etc. Buildings are furnished and are of concrete block construction. The buildings are based on weather requirements for the Denver, CO, area. The installation is based on a three-shift mining operation. Total cost is based on the combined floor space, in square meters, for the included buildings assuming single-story construction.

BASE CURVE

The total capital cost is based on a single cost curve having a building area (X), in square meters of space or having a production rate (T), in total metric tons of ore and waste per day. The curve is valid for areas of 20 to 2,400 m^2, or 14,000 to 55,000 mtpd, operating three shifts per day. The costs obtained from this curve are based on the assumption that these facilities will be used only for mining operations. If the mine and mineral processing plant are to share the same facilities, the user must determine (using a knowledge of the requirements) what can be jointly used and apportion the resulting cost to the mine and plant.

If the total number of needed square meters is not known, the following equation can be used to estimate the area required for surface buildings:

Total square meters = $10.7+0.00616(T)$
where T = metric tons ore and waste mined per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	51%
Construction supply cost......	49%

The total capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 23{,}587.146(X)^{0.422}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SQUARE\ METERS}}) = 12{,}029.444(X)^{0.422}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{SQUARE\ METERS}}) = 11{,}557.701(X)^{0.422}$

The total capital cost is $(Y_{C\ \mathrm{MTPD}}) = 3{,}417.367(T)^{0.403}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{MTPD}}) = 1{,}742.857(T)^{0.403}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{MTPD}}) = 1{,}674.51(T)^{0.403}$

ADJUSTMENT FACTORS

Shift Adjustment To adjust the capital cost for a different number of daily operating shifts, multiply the actual daily tonnage by the ratio of the base number of shifts (3) divided by the number of desired shifts. Then, use this modified production rate in place of actual daily tonnage in the preceding tonnage-square meter equation to obtain the adjusted building area. This factor need not be applied if actual building areas are known.

Temperature Factor The buildings are based on temperature requirements for the Denver, CO, area. For more moderate areas multiply the costs obtained from the base curve by the following factor:

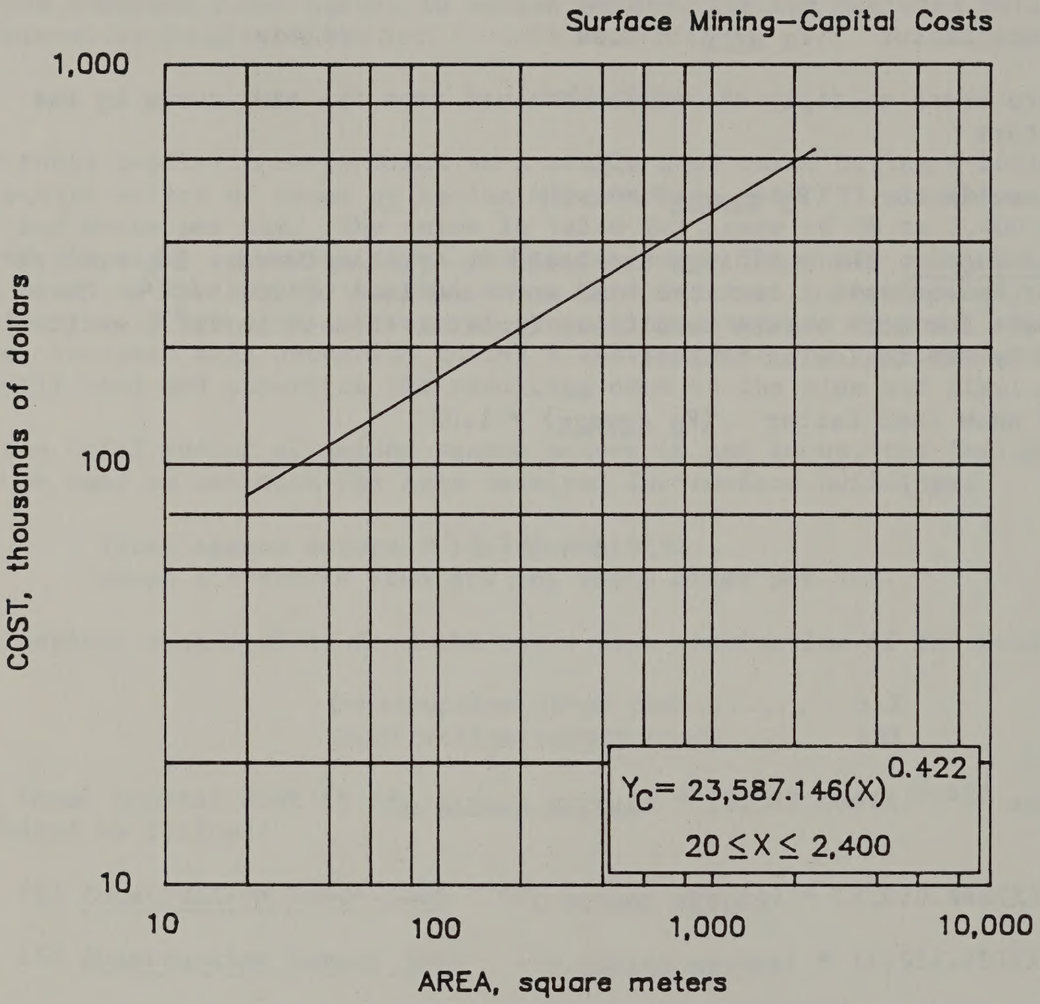
Temperature factor $(F_{T\ MILD}) = 0.94$

For more severe areas multiply the costs obtained from the base curve by the following factor:

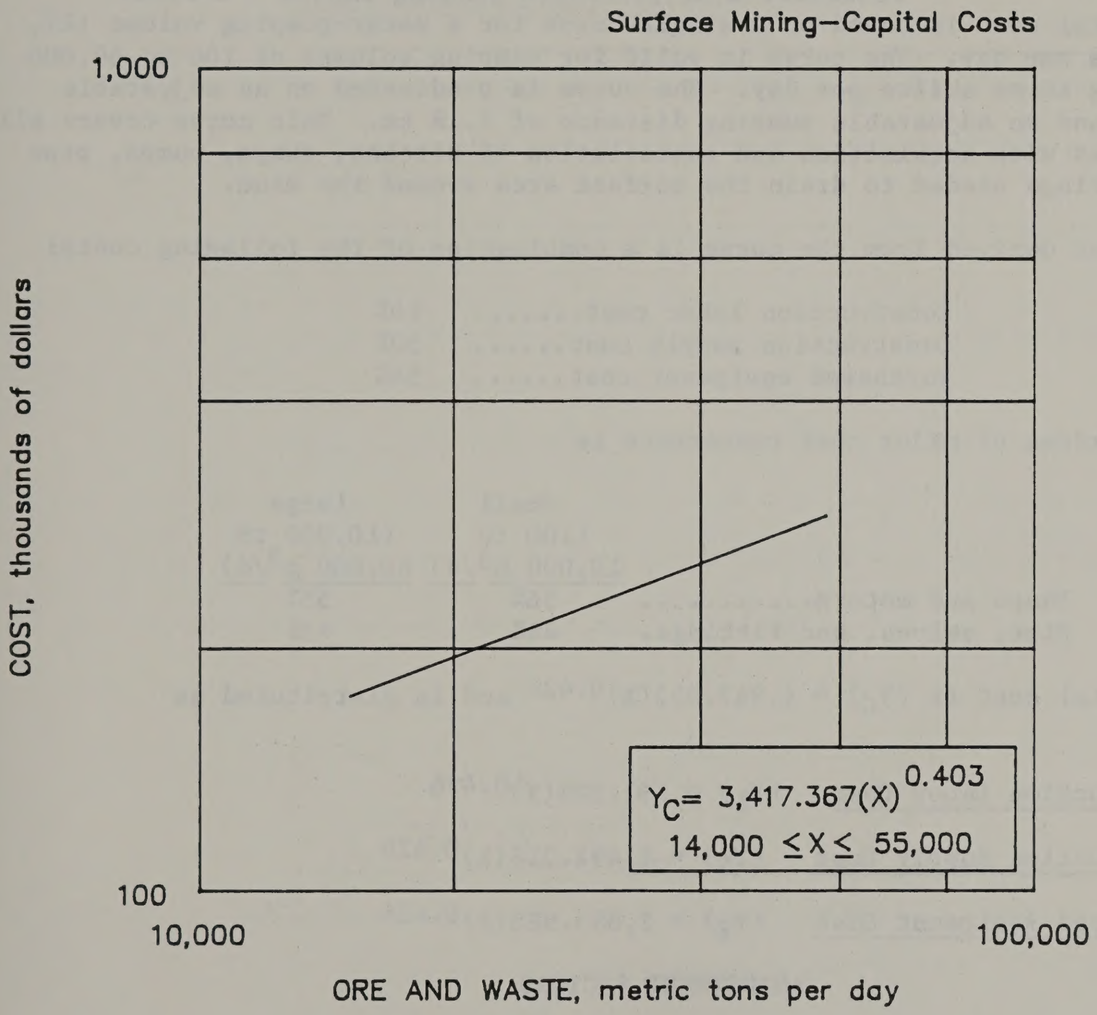
Temperature factor $(F_{T\ SEVERE}) = 1.08$

Wind and Snow Load Factor The buildings are based on typical Denver, CO, area requirements for an equivalent combined wind and snow load of 20 lb/ft^2. To adjust the costs for more severe conditions (greater than 40 lb/ft^2), multiply the costs by the following factor:

Wind and snow load factor $(F_{S\ SEVERE}) = 1.03$



2.2.4.9.a Surface buildings



2.2.4.9.b Surface buildings

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.10.1. WATER AND DRAINAGE SYSTEM
DRAINAGE SYSTEM

The curve applies to the most common dewatering method, which consists of pumping water out of the mine.

BASE CURVE

The total capital cost is based on a single curve for a water-pumping volume (X), in cubic meters per day. The curve is valid for pumping volumes of 100 to 60,000 m^3/d, operating three shifts per day. The curve is predicated on an adjustable head of 110 m and an adjustable pumping distance of 1.18 km. This curve covers all costs associated with acquisition and installation of ditches, sumps, pumps, pipe lines, and fittings needed to drain the surface area around the mine.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	16%
Construction supply cost......	30%
Purchased equipment cost......	54%

A typical breakdown of major cost components is

	Small (100 to 10,000 m^3/d)	Large (10,000 to 60,000 m^3/d)
Pumps and motors..........	56%	55%
Pipe, valves, and fittings.	44%	45%

The total capital cost is $(Y_C) = 4,947.052(X)^{0.426}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 791.528(X)^{0.426}$

(S) Construction Supply Cost $(Y_S) = 1,492.216(X)^{0.426}$

(E) Purchased Equipment Cost $(Y_E) = 2,685.988(X)^{0.426}$

ADJUSTMENT FACTORS

Pumping Head Factor The capital cost curve is based on 100-m static head (lift) and 10-m friction head. This friction head applies to a 1.18-km standard steel pipe line. For actual heads (H), multiply the cost obtained from the base curve by the following factor:

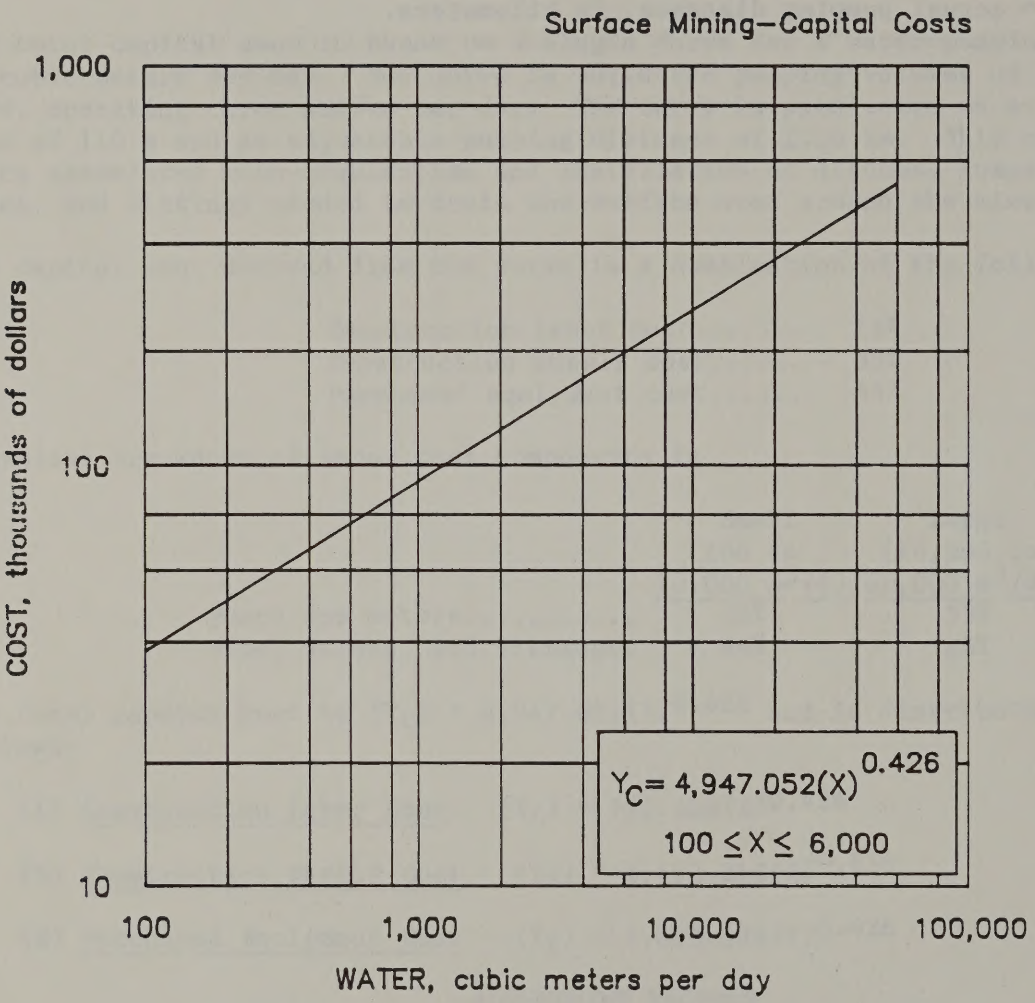
Pumping head factor $(F_P) = 0.65+[0.00318(H)]$
where H = actual head (static, friction, velocity, and fitting), in meters.

For preliminary estimates of H, add to the actual static head (lift) 8 m for each kilometer of new steel pipe line through which pumping is done.

For accurate determinations of H, add to the actual static head the sum of friction, velocity, and fitting heads obtained from hydraulics handbooks for actual pipe quality, pipe diameter, and pipe line pumping distance.

Pumping Distance Factor The capital cost curve is based on a 1.18-km pumping distance (0.18 km in the mine and 1 km outside). For actual distances, multiply the cost obtained from the base curve by the following factor:

Pumping distance factor $(F_D) = 0.490+0.431(D)$
where D = actual pumping distance, in kilometers.



2.2.4.10.1. Water and drainage system
DRAINAGE SYSTEM

2.2. SURFACE MINING--CAPITAL COSTS

2.2.4. MINE PLANT GENERAL OPERATIONS

2.2.4.10.2. WATER AND DRAINAGE SYSTEM
WATER SUPPLY SYSTEM (MAKEUP WATER)

Water is supplied from aquifers or surface sources to surface mines for dust control on haulage roads and for equipment cooling. The water supply system capital cost for a surface mine (and/or an adjoining mineral processing plant (section 6.1.8.14., IC 9143) is based on daily water consumption.

If total daily volume (mine and mineral processing makeup water) is known, the manual user should enter this volume in the equation given below (unless the processing plant is supplied with water from an independent source). The total cost may be allotted as follows[1]:

a) 9% to section 2.2.4.10.2. (surface mine).

b) 91% to section 6.1.8.14. (mineral processing plant IC 9143).

To estimate mine water demand, multiply the daily mine capacity (ore and waste) by 0.07. The 0.07 factor is the approximate number of cubic meters of water required per metric ton mined.

BASE CURVE

The total capital cost is based on a single curve for a water volume (X), in cubic meters per day and is valid for volumes of 1,000 to 150,000 m^3/d, operating three shifts per day. The curve is predicated on an average pumping head of 291 m, and pumping distances ranging from 3 to 53 km, and consists of wells, storage tanks, pipelines, distribution piping, pumps, and fittings.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	54%
Construction supply cost......	13%
Purchased equipment cost......	32%
Freight cost..................	1%

A typical breakdown of equipment major cost components is:

Pipe line.....................	58%
Pumps.........................	26%
Storage tanks.................	16%

---

[1] Percentages derived from U.S. Bureau of Mines IC 8285 dealing with water consumption for U.S. mines and mineral processing plants. Different percentages may be obtained if an actual breakdown of water consumption for the mine and mineral processing plants is known.

The total capital cost is $(Y_C) = 848.677(X)^{0.893}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 458.286(X)^{0.893}$

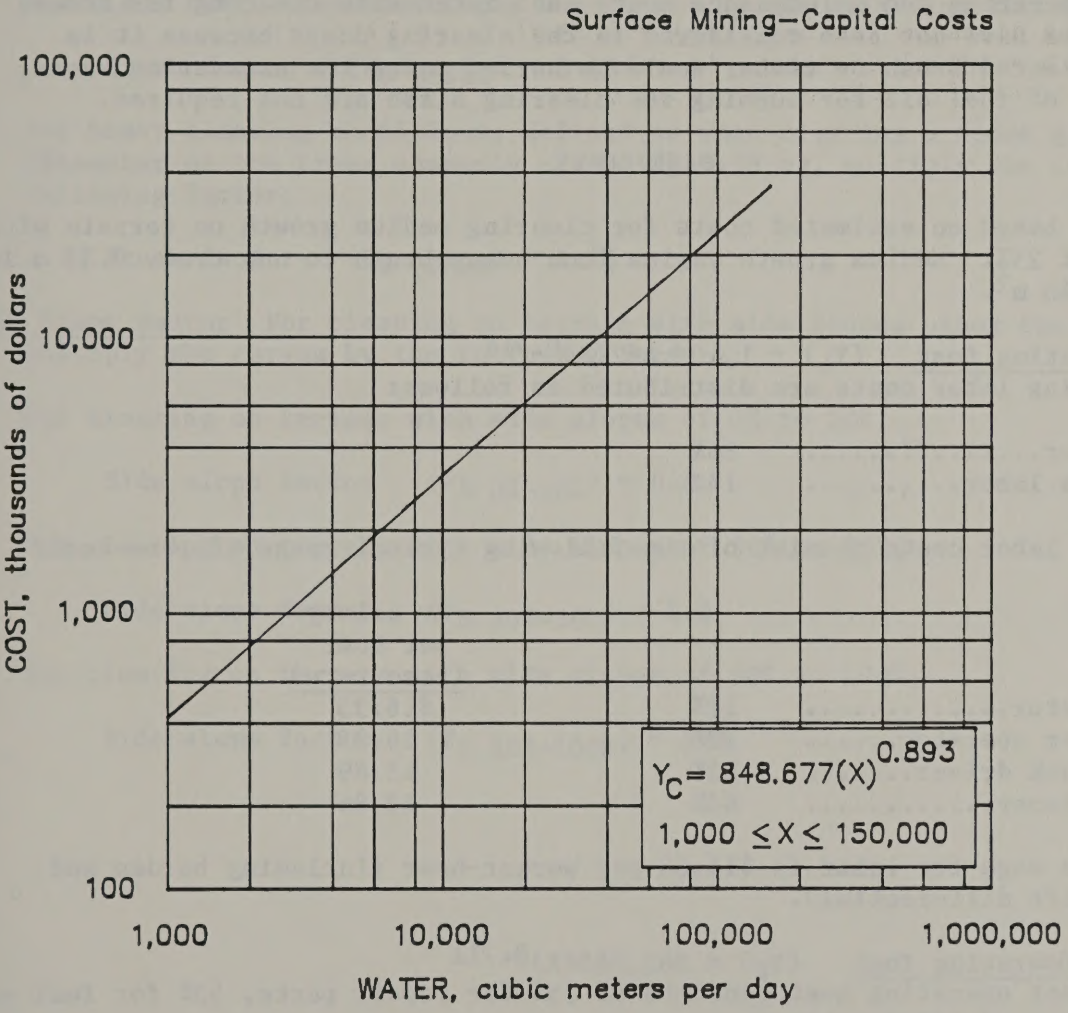
(S) Construction Supply Cost $(Y_S) = 110.328(X)^{0.893}$

(E) Purchased Equipment Cost $(Y_E) = 280.063(X)^{0.893}$

ADJUSTMENT FACTORS

Pumping Distance Factor To adjust the capital cost for the actual pumping distance, multiply the cost obtained from the base curve by the following factor:

Pumping distance factor $(F_D) = 0.030+[12.516(D)(X)^{-0.549}]$
where D = actual distance, in meters,
and X = daily volume, in cubic meters per day.



2.2.4.10.2. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.1.1. ACCESS ROADS
CLEARING

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with clearing for access roads. Supplies have not been considered in the clearing costs because it is assumed that cleared brush or timber would be buried under the excavation waste; thus, supplies of fuel oil for burning the clearing slash are not required.

BASE CURVE

The curves are based on estimated costs for clearing medium growth on terrain with a side slope of 25%. Medium growth varies from heavy brush to one tree, 0.33 m in diameter, per 40 m^2.

(L) Labor Operating Cost $(Y_L) = 1{,}135.467(X)^{0.711}$
The operating labor costs are distributed as follows:

Direct labor...............	86%
Maintenance labor..........	14%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator............	12%	$16.33
Wheel-loader operator......	12%	16.33
Flatbed-truck driver.......	12%	15.89
General laborer............	64%	13.86

The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 467.945(X)^{0.711}$
The equipment operating cost consists of 35% for repair parts, 53% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of

Dozer crawler..................................	31%
Wheel loader...................................	47%
Flatbed truck..................................	12%
Pickup truck...................................	9%
Chainsaws......................................	1%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawler.............	52%	48%	-
Wheel loader..............	36%	43%	21%
Flatbed truck.............	9%	80%	11%
Pickup truck..............	8%	90%	2%
Chainsaws.................	39%	61%	-

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factors

Brush factor $(F_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(F_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 30% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 30% to 50%,

Side slope factor $(F_{S\ 30\%-50\%}) = 1.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 2.5$

Burning Equation If fuel oil (for burning slash) or other supplies, such ascables and chokers, are used, add the following supply cost equation to the total cost per km. The total cost per kilometer for supplies is for a roadway of width (X), in meters, varying in width from 3 to 30 m.

(S) Supply Operating Cost $(Y_{S\ BURNING}) = 269.796[0.100(X)]^{-0.0303}$

This cost is multiplied by the total km, valid for values between 3.33 to 3,333.33 km, to obtain the capital cost.

For clearing operations from 1 to 500 ha (roadway width in meters multiplied by roadway length in meters multiplied by 0.0001), the supplies consist of 78% for fuel oil and 22% for tools, cables, and chokers. For clearing operations of 500 to 1,000 ha, supplies consist of 83% for fuel oil (for burning wood and scrub) and 17% for tools, cables, and chokers.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

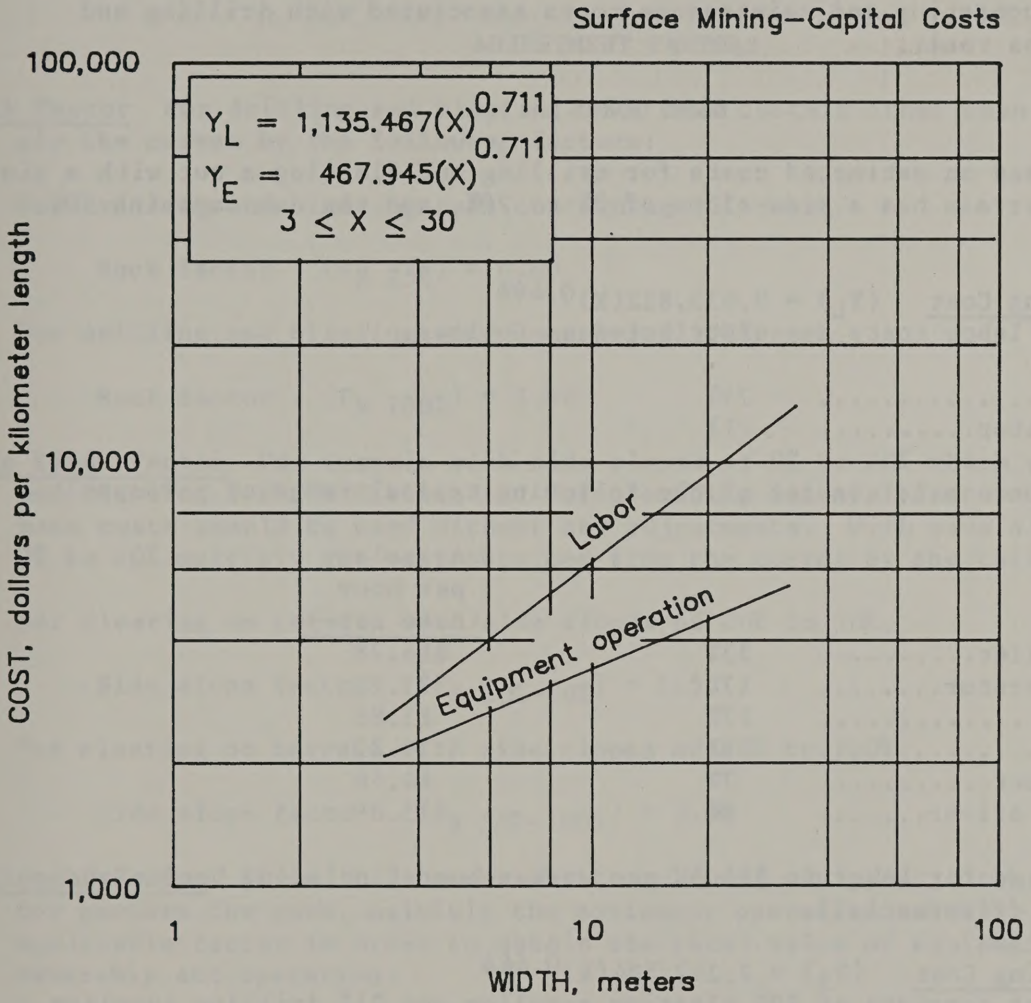
Shifts per day	1	2	3
Factor	1.91	1.68	1.61

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



2.2.6.1.1. Access roads
CLEARING

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.1.2. ACCESS ROADS
DRILL AND BLAST

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with drilling and blasting for access roads.

BASE CURVE

The curves are based on estimated costs for drilling and blasting a cut with a single ditch. The terrain has a side slope of 0% to 20%, and the cut contains 50% rock.

(L) Labor Operating Cost $(Y_L) = 9{,}633.822(X)^{0.496}$
The operating labor costs are distributed as follows:

Direct labor..............	79%
Maintenance labor.........	21%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Air-track driller.........	33%	$16.78
Compressor operator.......	17%	17.23
Chuck tender..............	27%	13.86
Powderman.................	8%	16.33
Powderman helper..........	7%	14.56
Flatbed-truck driver......	8%	15.89

The average wage for labor is $15.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7{,}247.524(X)^{0.644}$
The supply cost consists of 79% blasting supplies and 21% drilling supplies. Drilling supplies consist of percussion drill bits, rods, striking bars, and couplings; blasting supplies consist of dynamite, ANFO, electric blasting caps, and connecting wire.

(E) Equipment Operating Cost $(Y_E) = 4{,}109.384(X)^{0.496}$
The equipment operation curve consists of 51% for repair parts, 48% for fuel and lubrication, and 1% for tires.

The equipment operation curve consists of

Air-track drills...........	33%
Portable compressors.......	55%
Flatbed truck..............	7%
Pickup truck...............	5%

The equipment operating cost distribution is:

	Repair parts	Fuel & lube	Tires
Air-track drills...........	93%	7%	-
Portable compressors.......	34%	65%	1%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Rock Factor For drilling and blasting cuts that contain other than 50% rock, multiply the curves by the following factors:

For drilling and blasting cuts containing 25% rock,

Rock factor $(F_{R\ 25\%}) = 0.60$

For drilling and blasting cuts containing 100% rock,

Rock factor $(F_{R\ 100\%}) = 1.40$

Side Slope Factor For terrain with side slopes of 0% to 20% which require drilling and blasting for two ditches and for providing material for a minimum fill, the base costs should be used without any adjustments. With side slopes other than 0% to 20% multiply the cost obtained from the curves by the following factors:

For clearing on terrain with side slopes of 20% to 50%,

Side slope factor $(F_{S\ 20\%-50\%}) = 1.5$

For claering on terrain with side slopes of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 3.0$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

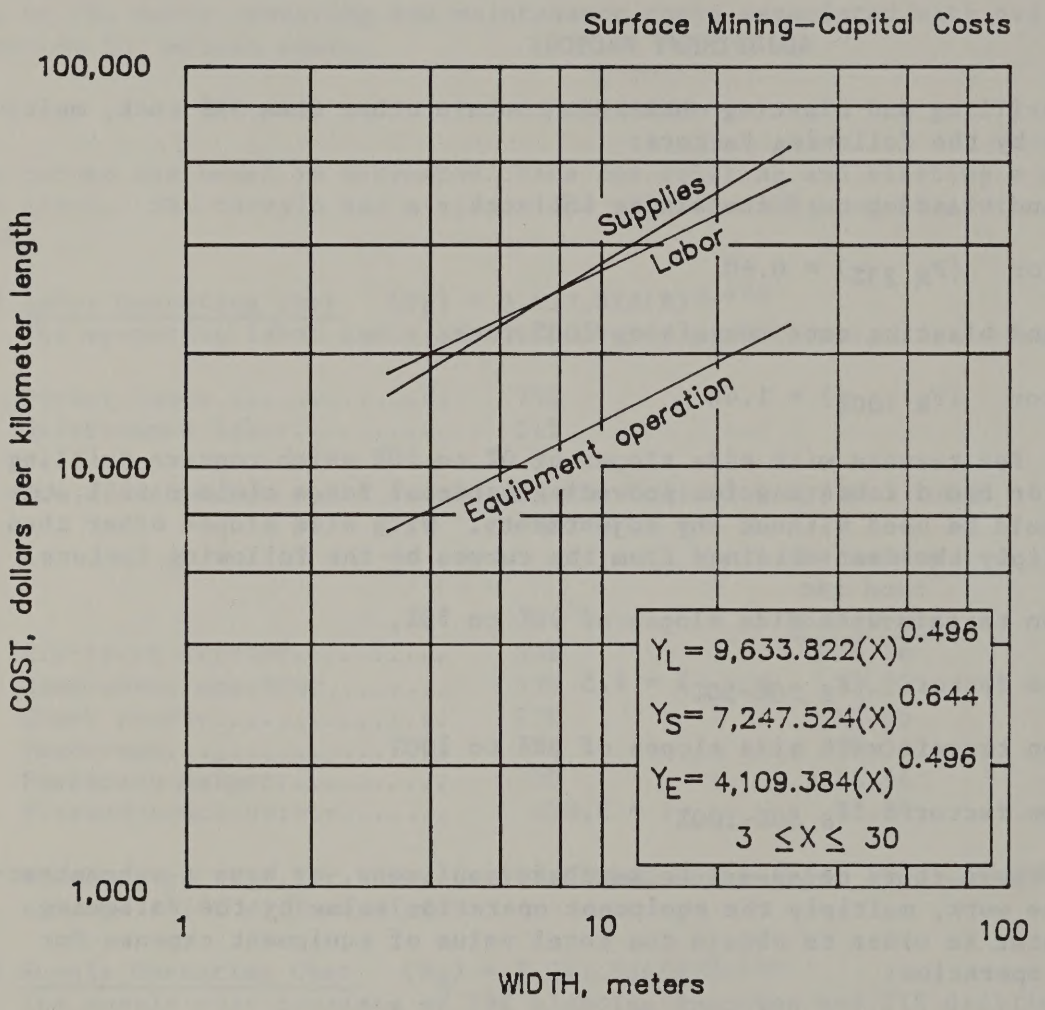
Shifts per day............	1	2	3
Factor....................	2.12	1.84	1.75

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs by the following factors:

Labor factor $(F_L) = 1.50$

Supply factor $(F_S) = 1.20$

Equipment operation factor $(F_E) = 1.20$



2.2.6.1.2. Access roads
DRILL AND BLAST

2.2. SURFACE MINING - CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.1.3. ACCESS ROADS - EXCAVATION

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with excavation for access roads.

BASE CURVES

The curves are based on a dozer excavation operation that is working on terrain with a side slope of 25%, side-casting from cuts or ditches to a 30-cm fill or to waste. The material to be excavated is either blasted rock or a common conglomerate that presents some difficulty in cutting and drifting.

(L) Labor Operating Cost $(Y_L) = 29.843(X)^{1.870}$
The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	60%	$16.33
Grader operator............	20%	16.33
Water-truck driver.........	20%	15.89

The average wage for labor is $16.24 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 27.128(X)^{1.870}$
The equipment operation curve consists of 46% for repair parts, 50% for fuel and lubrication, and 4% for tires.

The equipment operation curve consists of

Dozer crawlers.............	47%
Dozer-ripper crawler.......	25%
Motor grader...............	15%
Water truck................	9%
Pickup truck...............	4%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawlers.............	51%	49%	-
Dozer ripper crawler.......	53%	47%	-
Motor grader...............	45%	41%	14%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Side Slope Factor On terrain with a side slope other than 20% to 30% excavation costs can be determined by multiplying the costs obtained from the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{SS\ 0\%-20\%}) = [0.8(S)]^{0.600}(W)^{0.756}$
where S = side slope [defined as 1+(percent slope/100)],
and W = roadway width, in meters.

For clearing on terrain with side slopes of 30 to 100 percent,

Side slope factor $(F_{SS\ 30-100\%}) = [0.8(S)]^{3.958}(W)^{0.087}$
where:
S = side slope [defined as 1+(percent slope/100)],
and W = roadway width, in meters.

Material Factor For excavation of materials that are easy to cut and drift, multiply the costs obtained from the curves by the following factor:

Material factor $(F_{M\ EASY}) = 0.75$

For excavation of extremely wet and sticky material, multiply the curves by the following factor:

Material factor $(F_{M\ DIFFICULT}) = 1.33$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

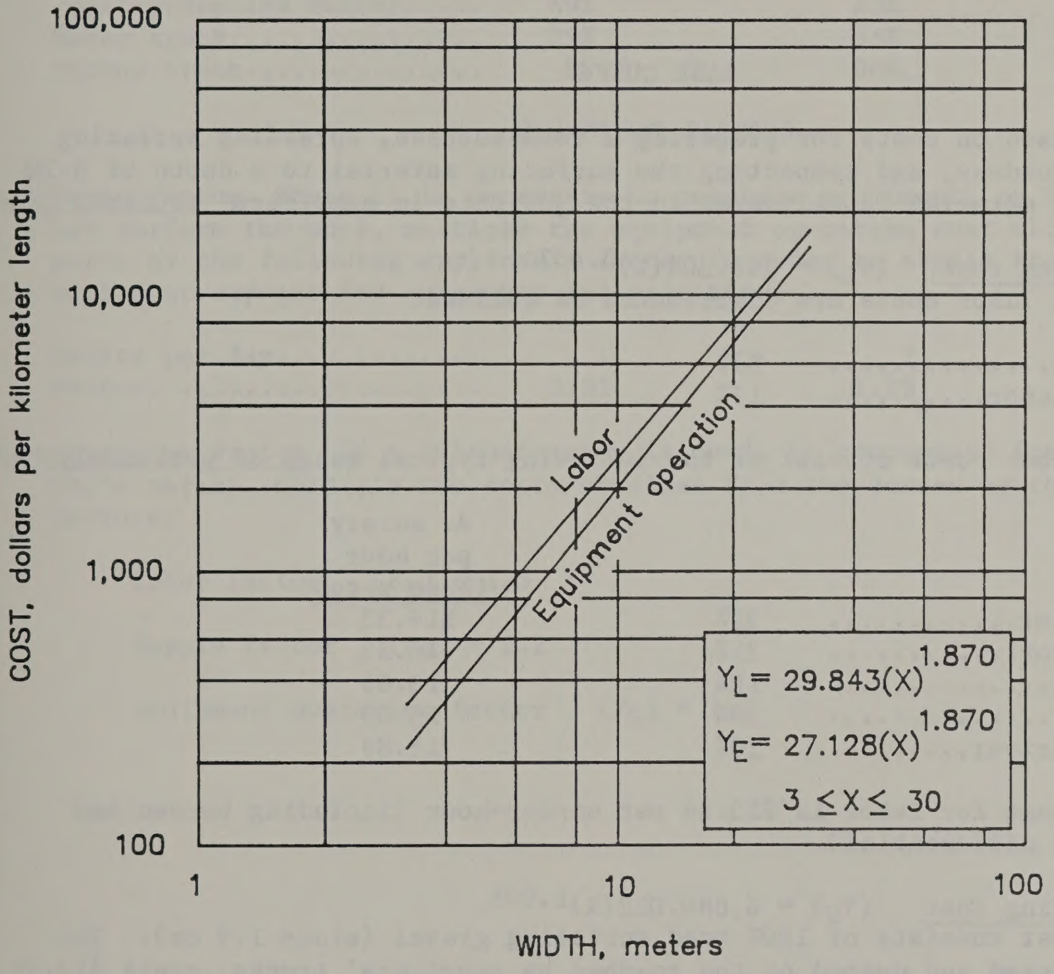
Shifts per day............	1	2	3
Factor....................	1.94	1.71	1.63

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Equipment operation factor $(F_E) = 1.2$

Surface Mining—Capital Costs



2.2.6.1.3. Access roads
EXCAVATION

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.1.4. ACCESS ROADS
GRAVEL SURFACING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with gravel surfacing of access roads.

BASE CURVE

The curves are based on costs for preparing a road subbase, spreading surfacing material on the roadway, and compacting the surfacing material to a depth of 0.20 m. The surfacing material is delivered to the job site in suppliers' trucks.

(L) Labor Operating Cost $(Y_L) = 293.304(X)^{0.667}$
The operating labor costs are distributed as follows:

Direct labor................	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Grader operator............	21%	$16.33
Roller operator............	21%	16.33
Dumpman....................	18%	13.86
Grade checker..............	20%	15.89
Water-truck driver.........	20%	15.89

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 6{,}880.012(X)^{1.006}$
The supply cost consists of 100% road surfacing gravel (minus 1.9 cm). The gravel, delivered and dumped on the roadbed by suppliers' trucks, costs $13.76 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 135.032(X)^{0.667}$
The equipment operation curve consists of 37% for repair parts, 51% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of

Motor grader...............	42%
Rubber-tired, self-propelled roller.....	19%
Water truck................	26%
Pickup truck...............	13%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Motor grader...............	45%	41%	14%
Rubber-tired, self-propelled roller.....	49%	40%	11%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

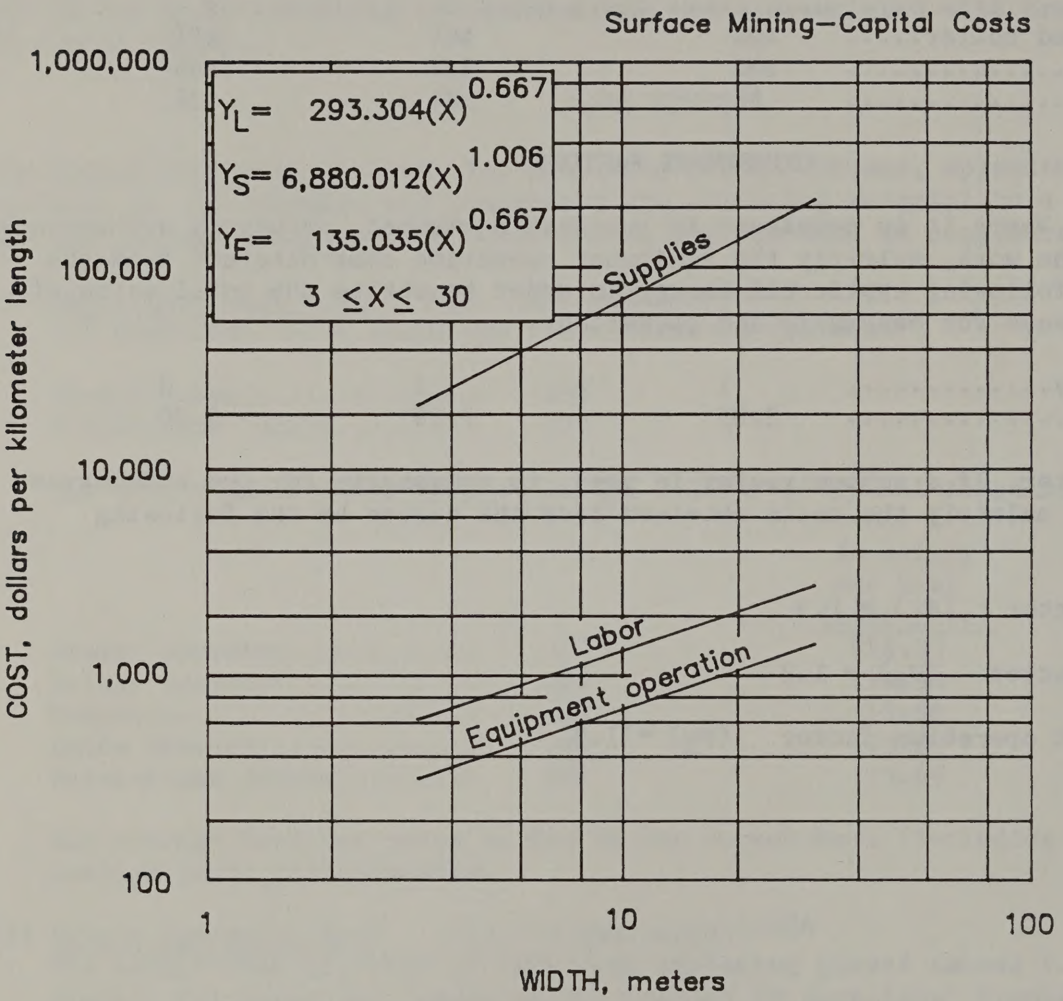
Shifts per day............	1	2	3
Factor....................	2.05	1.79	1.70

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



2.2.6.1.4. Access roads
GRAVEL SURFACING

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.1.5. ACCESS ROADS
PAVING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with paving of access roads.

BASE CURVE

The curves are based on a paving operation for laying and compacting hot-mix asphalt concrete (purchased locally from a hot-mix plant) to a depth of 5.1 cm. Costs to produce an appropriate paving road base are covered in section 2.2.6.1.4., Gravel Surfacing.

(L) Labor Operating Cost $(Y_L) = 117.710(X)^{1.005}$
The operating labor costs are distributed as follows:

Direct labor...............	80%
Maintenance labor..........	20%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Paver operator.............	13%	$16.33
Roller operator............	26%	16.33
General laborer............	22%	13.86
Rear-dump truck driver.....	39%	15.89

The average wage for labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2{,}661.382(X)^{1.005}$
The supply cost consists of 100 percent asphalt concrete (minus 1.9-cm hot mix). The asphalt concrete, supplied by a local hot-mix plant, costs $26.37 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 68.436(X)^{1.005}$
The equipment operation curve consists of 32% for repair parts, 58% for fuel and lubrication, and 10% for tires.

The equipment operation curve consists of

Asphalt paver..............	20%
Rubber-tired, self-propelled roller.....	5%
Steel-wheeled, tandem roller.............	5%
Rear-dump trucks...........	64%
Pickup truck...............	6%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Asphalt paver..............	68%	32%	-
Rubber-tired, self-propelled roller.....	43%	51%	6%
Steel-wheeled, tandem roller.............	50%	50%	
Rear-dump trucks...........	22%	63%	15%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Supply Factor The supplies cost should be adjusted for changes in the base asphalt-concrete price.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

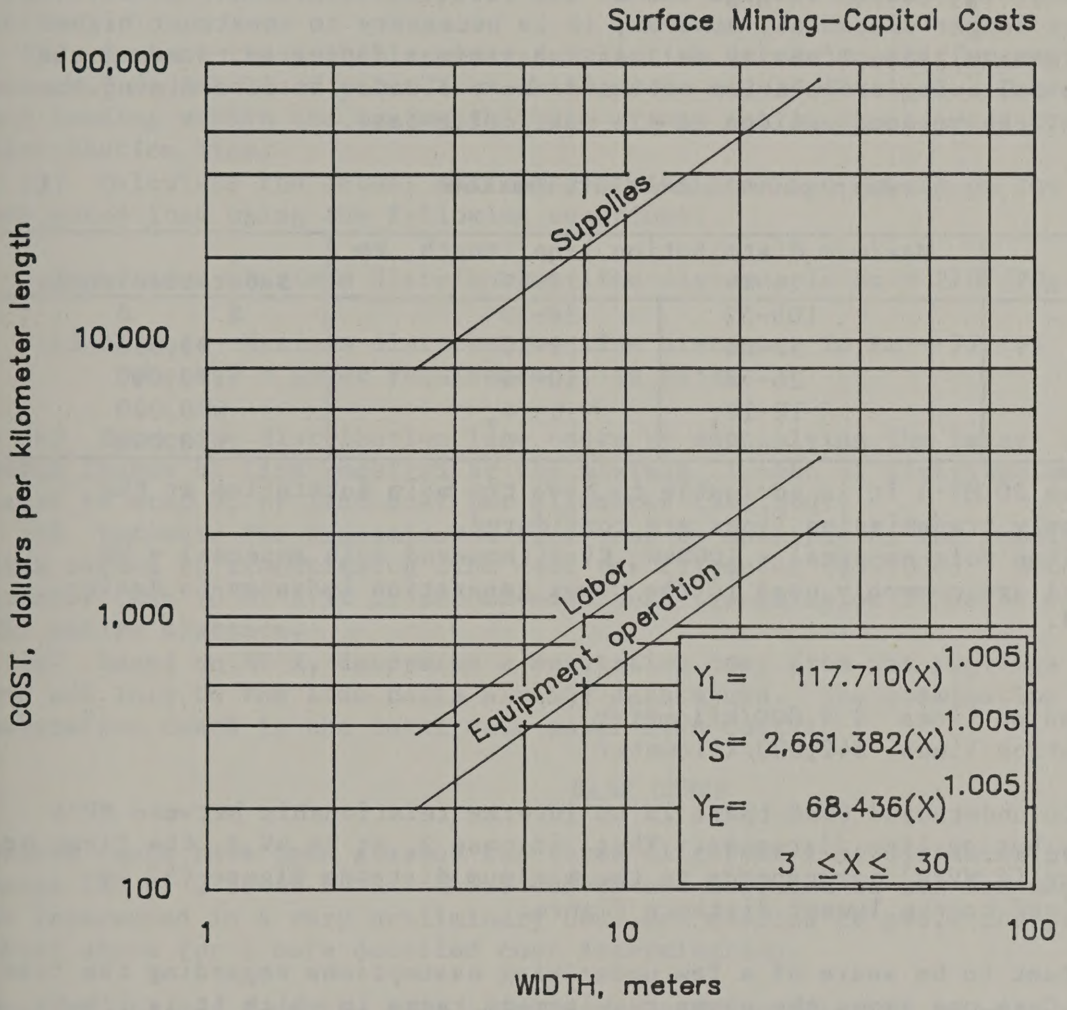
Shifts per day.............	1	2	3
Factor.....................	1.44	1.33	1.29

Subcontractor Factor If a subcontractor is used, to compensate for the sub-contractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



2.2.6.1.5. Access roads
PAVING

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.2. MAIN POWER LINES

If power is to be obtained from a local power company, it is generally necessary to construct new facilities to connect the mine site to the existing power line network. This cost is usually borne by the mine company that desires to receive the service. For shorter distances and lower maximum power loads this may simply entail extending existing, medium voltage (13-24 kV) distribution lines. To satisfy greater loads over longer distances, however, it is necessary to construct higher voltage (115 kV) transmission lines as well as substations dedicated to serve the mine solely. The following tablulation will aid the evaluator in determining the appropriateness of the various options to his particular case.

Main power line distribution

Case	Load Range(MV·A)	Maximum distribution line length, km 24 kV	13 kV	Substation costs
1....	2- 4	105-52	38-19	$ 0
2....	4- 8	52-26	19-10	95,000
3....	8-12	26-18	10- 6	289,000
4....	12-20	18-10	6- 4	630,000
5....	20	0[1]	0[1]	630,000

[1] At greater than 20 MV·A it is advisable to have the main substation at the mine site, thus only transmission lines are considered.

Note--MV·A(million volt amperes) = 1000kW; KV·A(thousand volt amperes) = kW Both MV·A and KV·A are commonly used in the power generation industry to designate power demand.

LINE COSTS:

Transmission lines	$59,000/kilometer
Distribution lines	$42,000/kilometer

It is important to understand that there is an inverse relationship between MV·A and maximum distribution line distances. Thus, in case 2, at 24 kV.A, the first or lowest load figure (4 MV·A) corresponds to the maximum distance figure (52 km and the highest load to the lowest distance figure.

It is also important to be aware of a few underlying assumptions regarding the five separate cases. Case one shows the power requirement range in which it is likely that existing distribution lines could supply the needed power. Thus there is no substation expense. The second and third cases assume that minor and major modifications of an existing substation will be required, respectively. They also assume that new line needed will originate from that modified substation. For cases 4 and 5 the large power requirements necessitate the construction of a completely new, dedicated substation. This facility will thus have to be fed by extending an existing high-voltage transmission line. In the instance of case 4 the site of the substation is as near the existing transmission line network as practicable; for case 5 the substation is assumed to be at the mine site.

The costs contained in this section assume that the power company that will be supplying the power will design and construct the line. Principal costs categories included are right-of-way purchase and clearing, access road construction, line and substation construction, permitting, and preconstruction design.

The procedure for determining the system cost and requirements are as follows:

(1) Estimate the maximum power demand that the mine will require. If not available, an estimate of this value may be made by the techniques contained in the appropriate mine and beneficiation electrical system sections contained in this report. It is recommended that, for estimating purposes, horsepower and kW (or KV•¯ A) be considered to be equivalent. Motor efficiencies as well as other system power losses generally account for much of the difference between the two units.

(2) Contact the probable power supplier to determine the "nearest useable source," or likeliest point from which power may be obtained. Depending upon present loading within the system this may or may not be the nearest transmission or distribution line.

(3) Calculate the actual maximum distribution line length on the basis of the projected load using the following equations:

24-kV load--Maximum distribution line distance in km = 210/(P)

13-kV load--Maximum distribution line distance, in km = 77/(P)
where P = power requirements, in MV•A.

(4) Determine distribution line costs by multiplying the lesser of either the total length of line required or the maximum length of distribution line as calculated in step 3, by line cost per kilometer ($42,000).

(5) Estimate the transmission line cost by multiplying the remaining length of line needed by transmission line cost per kilometer ($59,000). Note that for greater than 20 MV•A it is recommended that transmission lines be installed for the entire distance.

(6) Based on MV•A, determine a substation cost from the previous tablulation and add this to the line costs already determined. The combination of line and substation costs is the total main power line cost.

BASE CURVE

System costs have been graphed for three different line distances over the load-range (X) of 2 to 40 MV•A. These curves are included to aid the manual user that is interested in a very preliminary cost and desires to avoid the procedure outlined above for a more detailed cost determination.

Freight charges from the east coast manufacturing plant to Denver, CO, for the major purchased equipment has been determined to be:

Transformer, 32 mt	$7,500
Oil breaker - 3 at 13 mt each	$9,600

All other equipment and materials are considered to be locally available in Denver, CO.

The total capital cost is based on single curves having power loads (X), in megavolt amperes. The curves are valid for power loads of 2 to 40 MV•A.

The capital cost derived from the curve is a combination of the following costs:

	Small (2 to 20 MV•A)	Large (20 to 40 MV•A)
Construction labor cost	50%	47%
Construction supply cost	50%	37%
Purchased equipment cost	-	16%

The total 10-km main powerline capital cost is
$(Y_{C\ 10\ KM\ LINE}) = 207{,}826.608(X)^{0.563}$ and is distributed as follows:

(L) Construction labor cost $(Y_{L\ 10\ KM\text{-}SMALL}) = 103{,}913.304(X)^{0.563}$
(S) Construction supply cost $(Y_{S\ 10\ KM\text{-}SMALL}) = 103{,}913.304(X)^{0.563}$

(L) Construction labor cost $(Y_{L\ 10\ KM\text{-}LARGE}) = 97{,}678.506(X)^{0.563}$
(S) Construction supply cost $(Y_{S\ 10\ KM\text{-}LARGE}) = 76{,}895.844(X)^{0.563}$
(E) Purchased equipment cost $(Y_{E\ 10\ KM\text{-}LARGE}) = 33{,}252.257(X)^{0.563}$

The total 25-km main powerline capital cost is
$(Y_{C\ 25\ KM\ LINE}) = 644{,}990.250(X)^{0.370}$ and is distributed as follows:

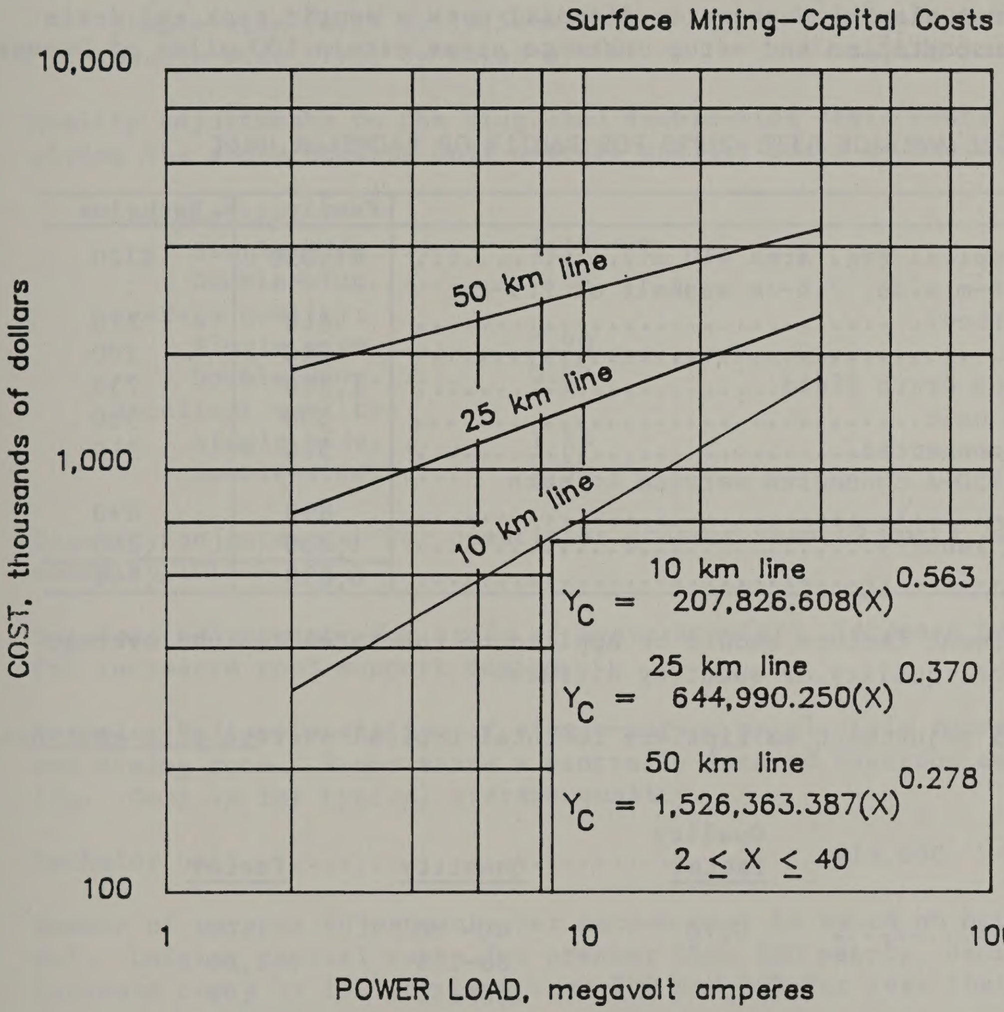
(L) Construction labor cost $(Y_{L\ 25\ KM\text{-}SMALL}) = 322{,}495.125(X)^{0.370}$
(S) Construction supply cost $(Y_{S\ 25\ KM\text{-}SMALL}) = 322{,}495.125(X)^{0.370}$

(L) Construction labor cost $(Y_{L\ 25\ KM\text{-}LARGE}) = 303{,}145.418(X)^{0.370}$
(S) Construction supply cost $(Y_{S\ 25\ KM\text{-}LARGE}) = 238{,}646.392(X)^{0.370}$
(E) Purchased equipment cost $(Y_{E\ 25\ KM\text{-}LARGE}) = 103{,}198.440(X)^{0.370}$

The total 50-km main powerline capital cost is
$(Y_{C\ 50\ KM\ LINE}) = 1{,}526{,}363.387(X)^{0.278}$ and is distributed as follows:

(L) Construction Labor cost $(Y_{L\ 50\ KM\text{-}SMALL}) = 763{,}181.694(X)^{0.278}$
(S) Construction supply cost $(Y_{S\ 50\ KM\text{-}SMALL}) = 763{,}181.694(X)^{0.278}$

(L) Construction labor cost $(Y_{L\ 50\ KM\text{-}LARGE}) = 717{,}390.792(X)^{0.278}$
(S) Construction supply cost $(Y_{S\ 50\ KM\text{-}LARGE}) = 564{,}754.453(X)^{0.278}$
(E) Purchased equipment cost $(Y_{E\ 50\ KM\text{-}LARGE}) = 244{,}218.142(X)^{0.278}$



2.2.6.2. Main power lines

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.3. TOWNSITE

The following housing costs are for a typical average quality park based on using trailers or manufactured 'mobile home' housing containing between 150 and 200 units. Costs are quoted per individual housing unit. Costs are factored by using the Bureau of Labor Statistics Industrial Materials Cost Index. Site costs do not include land site acquisition, construction of utility trunk lines to the site, or a wastewater treatment plant. Wastewater disposal uses a septic tank and drain field; however, transportation and setup costs to areas within 100 miles of Denver, CO, are included.

TYPICAL AVERAGE SITE COSTS FOR FAMILY OR BACHELOR UNIT

	Family	Bachelor
Site preparation (typical avg. area 410 m^2)............	$1,050	$320
Streets (7.9- to 9.8-m wide, 7.6-cm asphalt or 7.5-cm gravel edged or curbed)................................	810	270
Patios and walks..	610	200
Septic tank, includes drain field......................	1,360	750
Water, connected to unit................................	550	550
Gas, low-pressure, connected...........................	310	310
Electrical, 80- to 150-A connected service to each unit..	890	890
Office, recreation, laundry............................	1,250	1,250
Total..	6,830	4,540

The following adjustment factors should be applied to the total typical average site cost where either quality or quantity differs.

Site preparation adjustment multipliers to total typical average site cost are as follows:

Quality description	Quality factor	Quantity	Factor
Low (300 m^2/space)........	0.70	40- 80	1.07
		80-125	1.00
		150-250	.92
Average (410 m^2/space)....	1.00	50-125	1.10
		150-200	1.00
		250-300	.95
Good (520 m^2/space).......	1.30	50-150	1.10
		175-200	1.00
		250-350	.97

In addition, the following accessories may also be required:

Skirting at base of trailer..................	$620.00
Landing and steps............................	360.00
Canopies over landings.......................	550.00
Air conditioning--using existing heater.......	840.00

HOUSING UNITS

Family Units--With living, dining, kitchen, bath, and sleeping facilities for two adults and two to four children. Cost is for typical average quality.

Single-wide (4.27 by 19.50 m)	$15,400
Double-wide (7.31 by 14.63 m)	26,400

Quality adjustments to the singleand double-wide basic costs are made by multiplying the above housing unit average quality costs by the following factors:

Low quality:	
Single wide......	1.12
Double-wide......	1.16
Average quality:	
Single wide......	0.90
Double-wide......	0.87
Excellent quality:	
single wide......	1.25
double-wide......	1.34

Quantity adjustments--For quantities greater than 10 units, decrease overall costs by 10%.

Snowload adjustment--For areas of heavy snowfall, increase basic unit costs 5% for increased roof support design.

Bachelor Units--Consisting of single-person motel-style rooms with a kitchen and dining room. Rooms share a centrally located restroom and shower facility. Cost is for typical average quality.

Bachelor unit................................	$15,000

Number of persons adjustment--Per person cost is based on housing 400 personnel. Lodging capital costs for greater than 500 people, decrease costs by 10%. Increase costs by 15% for less than 300 and 20% for less than 200.

PRIMARY UTILITIES

Electrical, cost per linear meter:	
Main overhead electric powerlines..........	$26.32
Lateral overhead lines.....................	8.25

Water, cost per linear meter:	
Main, 15.24-cm plastic (add or deduct $5.75 per 2.54-cm diam.).....................	$35.80
Lateral, 2.54-cm............................	17.22

2.2. SURFACE MINING--CAPITAL COSTS

2.2.6. INFRASTRUCTURE

2.2.6.4.1. WASTEWATER TREATMENT CLARIFICATION

Clarification capital cost is for the acquisition and installation of equipment for water clarification and softening by precipitation and/or coagulation. The all metal solids-contact clarifier combines into one operation--quick mixing, flocculation, clarification, and sludge thickening. The unit will selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, hardness, alkalinity, taste, and odor. The cost curve is based on clarifiers ranging in diameter from 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2).

BASE CURVES

Total cost is based on a single cost curve having a tank diameter of (X) in meters. The curve includes all costs associated with acquisition and installation of concrete pad, clarifier structure, and control-monitor equipment for sludge level and sludge density control.

The total clarification capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	19%
Construction supply cost......	5%
Purchased equipment cost......	76%

The total clarification capital cost is $(Y_C) = 15{,}631.070(X)^{0.991}$ and is distributed as follows:

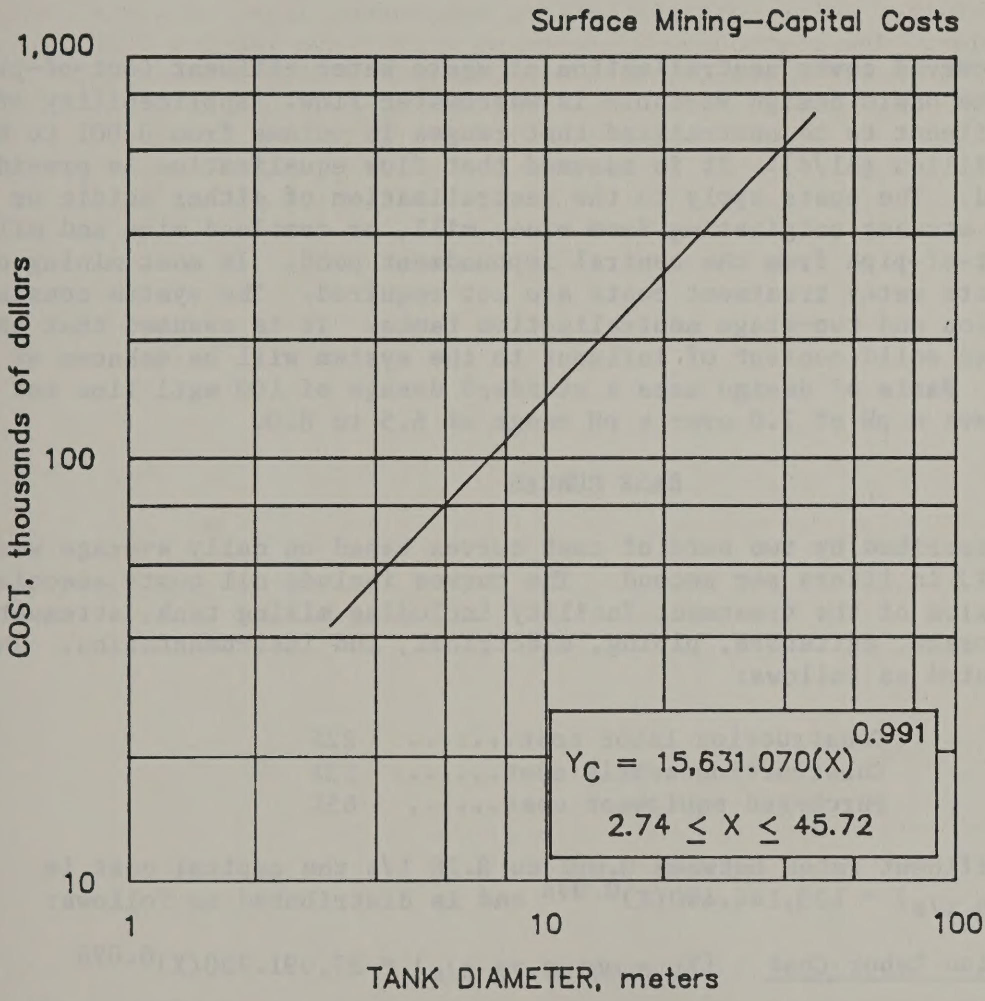
(L) Construction Labor Cost $(Y_L) = 2{,}969.910(X)^{0.991}$

(S) Construction Supply Cost $(Y_S) = 781.550(X)^{0.991}$

(E) Purchased Equipment Cost $(Y_E) = 11{,}879.610(X)^{0.991}$

Note--Sizing of clarifier is based on one principal parameter--rise rate-- the vertical velocity of the stream through the clarifier. If the diameter or cross-sectional area of the clarifier is unknown, and the feed flow rate is known and the rise rate is assumed to be 0.015 m/min, then the diameter (D), or equivalent cross-sectional area, of the clarifier can be estimated with the equation:

Clarifier diameter $(D) = 1.128[(Q)/(R)]^{0.500}$
where R = rise rate, in meters per minute,
and Q = design flow rate, in cubic meters per minute.


Surface Mining—Capital Costs

2.2.6.4.1. Wastewater treatment
CLARIFICATION

2.2.6.4.2. WASTE WATER TREATMENT NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The capital cost curves cover neutralization of waste water effluent (out-of-pipe) when required. The basic design variable is wastewater flow. Applicability of the curves are for effluent to be neutralized that ranges in volume from 0.001 to 876 L/s (22.8 to 20 million gal/d). It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mgLl lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

Total costs are described by two sets of cost curves based on daily average waste water flow rate (X) in liters per second. The curves include all costs associated with the construction of the treatment facility including mixing tank, attenuation tank, chemical storage, agitators, piping, electrical, and instrumentation. These costs are distributed as follows:

Construction labor cost.......	22%
Construction supply cost......	13%
Purchased equipment cost......	65%

For waste water effluent rates between 0.001 to 8.76 L/s the capital cost is $(Y_{C\ 0.001\text{-}8.76\ L/s}) = 123{,}144.490(X)^{0.094}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ 0.001\text{-}8.76\ L/s}) = 27{,}091.780(X)^{0.094}$

(S) Construction Supply Cost $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 16{,}008.780(X)^{0.094}$

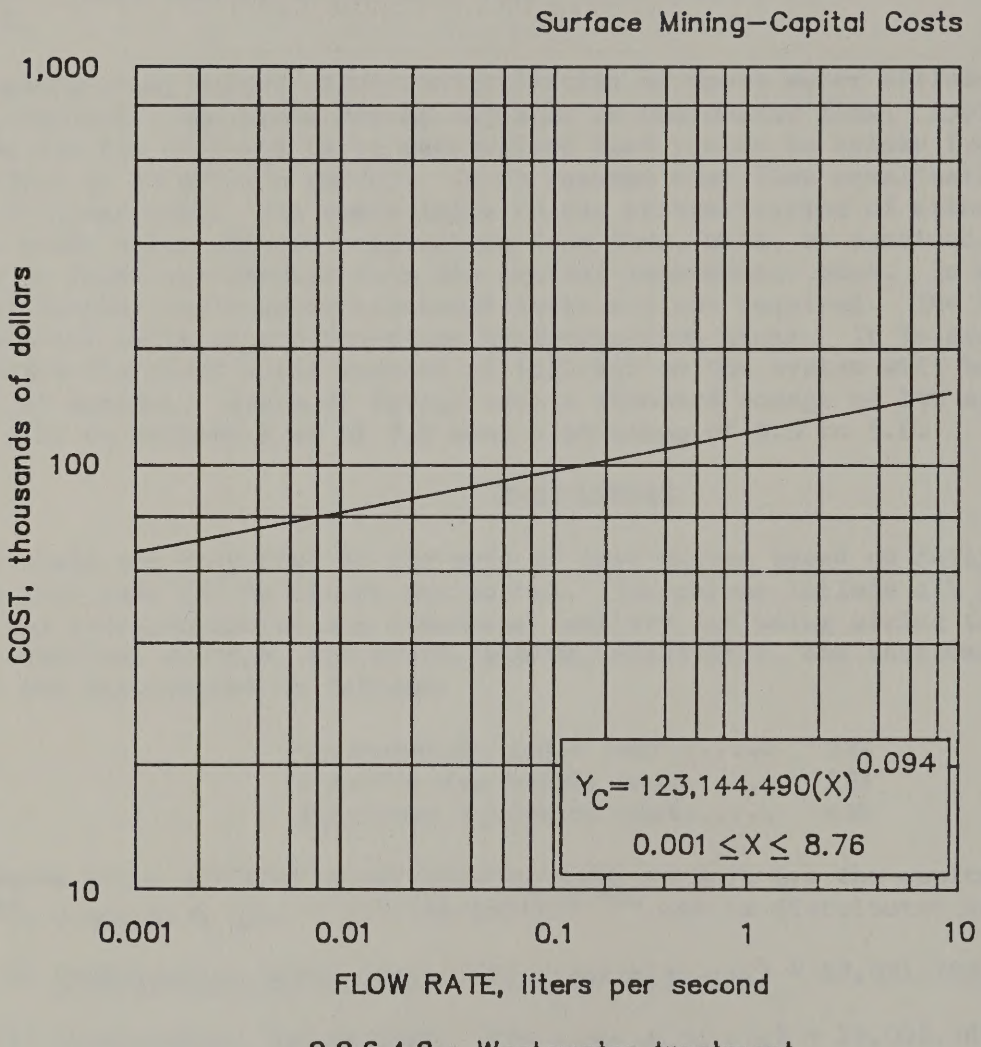
(E) Purchased Equipment Cost $(Y_{E\ 0.001\text{-}8.76\ L/s}) = 80{,}043.930(X)^{0.094}$

For waste water effluent rates between 8.76 to 876 L/s the capital cost is $(Y_C\ 8.76\text{-}876\ L/s) = 26{,}346.39(X)^{0.562}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L$ 8.76-876 L/s$) = 5{,}796.21(X)^{0.562}$

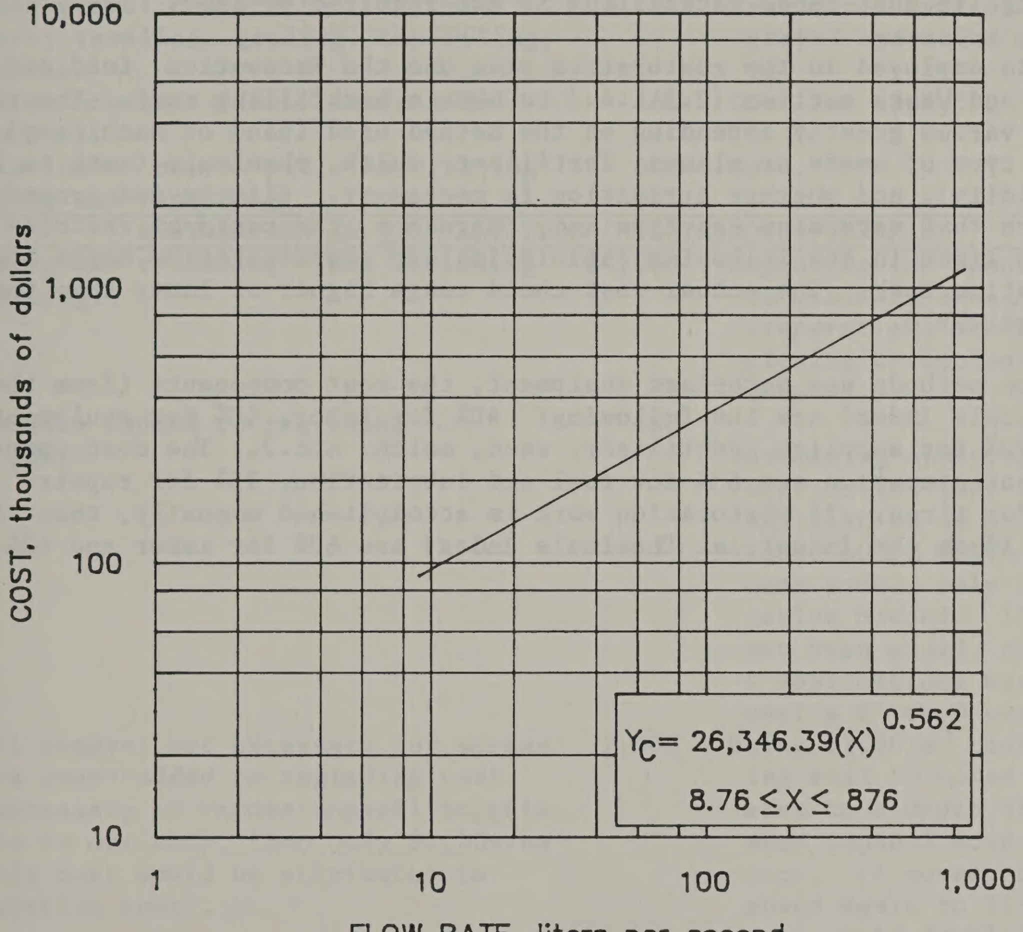
(S) Construction Supply Cost $(Y_S$ 8.76-876 L/s$) = 3{,}425.03(X)^{0.562}$

(E) Purchased Equipment Cost $(Y_E$ 8.76-876 L/s$) = 17{,}125.15(X)^{0.562}$



2.2.6.4.2.a Wastewater treatment
NEUTRALIZATION

Surface Mining—Capital Costs



2.2.6.4.2.b Wastewater treatment
NEUTRALIZATION

2.2. SURFACE MINING--CAPITAL COSTS

2.2.7. RESTORATION DURING CONSTRUCTION

Mine restoration is the process of initiating and accelerating the natural continuous trend toward recovery (stabilization, etc.), the type of environment (desert, flatland, grasslands, mountains, etc.), and the restoration requirements by law in any given State (which range from none to very strict). Some States require permits prior to disturbing the ground surface. Typically, the permit specifies that the area must be reclaimed, hectare for hectare, to a use similar to the prior use or other beneficial use. Most restoration activities for mines include regrading and leveling plant sites (and revegetation of the disturbed area) but do not include backfilling (in most cases backfilling is not required by law).

If backfilling is employed in the restoration plan use the Excavation, Load and Haul Overburden and Waste section (2.2.1.4.) to obtain backfilling cost. The revegetation cost varies greatly depending on the method used (hand or machinery), materials used, type of seeds or plants, fertilizer, mulch, chemicals (such as lime for reducing acidity), and whether irrigation is necessary. Climate and ground slope are factors that determine the type and, therefore, the costs of restoration. The costs given in the following tablulation are representative costs for a specific restoration task. The actual cost could range higher or lower than the cost given in the table.

Where restoration methods use motorized equipment, the cost components (from the Industrial Chemicals Index) are the following: 40% for labor, 40% for equipment operation, and 20% for supplies (fertilizer, seed, mulch, etc.). The cost components for equipment operation are 65% for fuel and lubrication, 25% for repair parts, and 10% for tires. If restoration work is accomplished manually, then the cost components (from the Industrial Chemicals Index) are 60% for labor and 40% for supplies.

COST COMPARISONS OF RESTORATION METHODS

	Cost per hectare	Remarks
SPECIFIC RESTORATION WORK (INDEPENDENT OF CLIMATE OR GEOGRAPHY)		
Revegetation on steep slope--roadside slopes, tailing slopes, or waste dump slopes, using hydroseeder with fiber mulch.	$1,000-1,500	Based on using 18 kg/ha of seed, 73 kg/ha of fertilizer, and expenses to use a boom crane, pickup truck, 2 equipment operators, and a swamper.
Transplanting trees or shrubs by hand on moderate to steep slopes.	5,000	Assume 2,500 trees hand planted per hectare at $2 per tree or shrub.
Sand and gravel restoration, includes placers; leveling, grading, topsoiling, reseeding.	3,000	Based on a typical sand-and-gravel operation near Denver, CO.
Annual maintenance (fertilizers added for above).	160	Cost for applying fertilizer.
Restoration of borrow pit - backfilling leveling and reseeding.	400-600	None.
RESTORATION IN HIGH ALTITUDE (MOUNTAINOUS) TERRAIN		
Regrading and reseeding - not including topsoiling.	$4,000	Regrading for adequate drainage to minimize erosion, seedbed preparation, and reseeding (including transplanting trees and shrubs).
Maintenance (added to regrading cost cost).	130	Purchasing-applying fertilizer--application cost for 1 yr. If application is on area where at least 30-cm depth of topsoil has been added, only 1 year's application needed. If topsoil has not been added, then as many as 4 applications may be required over a 6- to 8-year period.
Topsoil removal not necessary for access to ore body--added to regrading cost (if necessary to remove topsoil to gain access to ore body, then only $1,300/ha of this cost would be attributed to restoration cost).	7,000	Using $2.30/m^3 cost of stockpiling soil to cover a disturbed area to a depth of 30 cm. Assume topsoil moved and emplaced once. If moved, then stored and moved again to final placement, cost could double).
RESTORATION IN ARID AND SEMIARID LANDS		
Soil added	$5,000	Required to achieve restoration on only the most severely disturbed sites. Generally serves to accelerate the rate of achieving permanent self-sustaining vegetation.

COST COMPARISONS OF RESTORATION METHODS--Continued

	Cost per hectare	Remarks
RESTORATION IN ARID AND SEMIARID LANDS--Continued		
Seeding and irrigation in arid climate on tailings dams, waste dump sites, road slopes.	$12,000-15,000	Irrigation system cost (sprinkler or drip tube) is estimated at $8,000/ha. Water assumed to be pumped on site at annual rate of 12,000 to 18,000 m^3/ha at $63 to $67 per 1,000 m^3 of water.
Seed and fertilizer broadcast on surface --no soil coverage or mulch.	700	Minimum slope where seed will cover naturally with soil. Seed broadcast manually.
Hydromulching with 680 kg wood fiber per hectare plus seed and fertilizer.	1,900-2,500	Most common southwestern U.S. hydromulch mix; will hold seed and fertilizer in place on steep and smooth slopes.
Straw or hay broadcast with straw blower on surface at 3,400 kg/ha.	2,500	Very effective as energy absorber and mulch. Not used on steep slopes. Cost increase significant if slopes over 14 m from access.

2.2. SURFACE MINING--CAPITAL COSTS

2.2.8. ENGINEERING AND CONSTRUCTION MANAGEMENT FEES

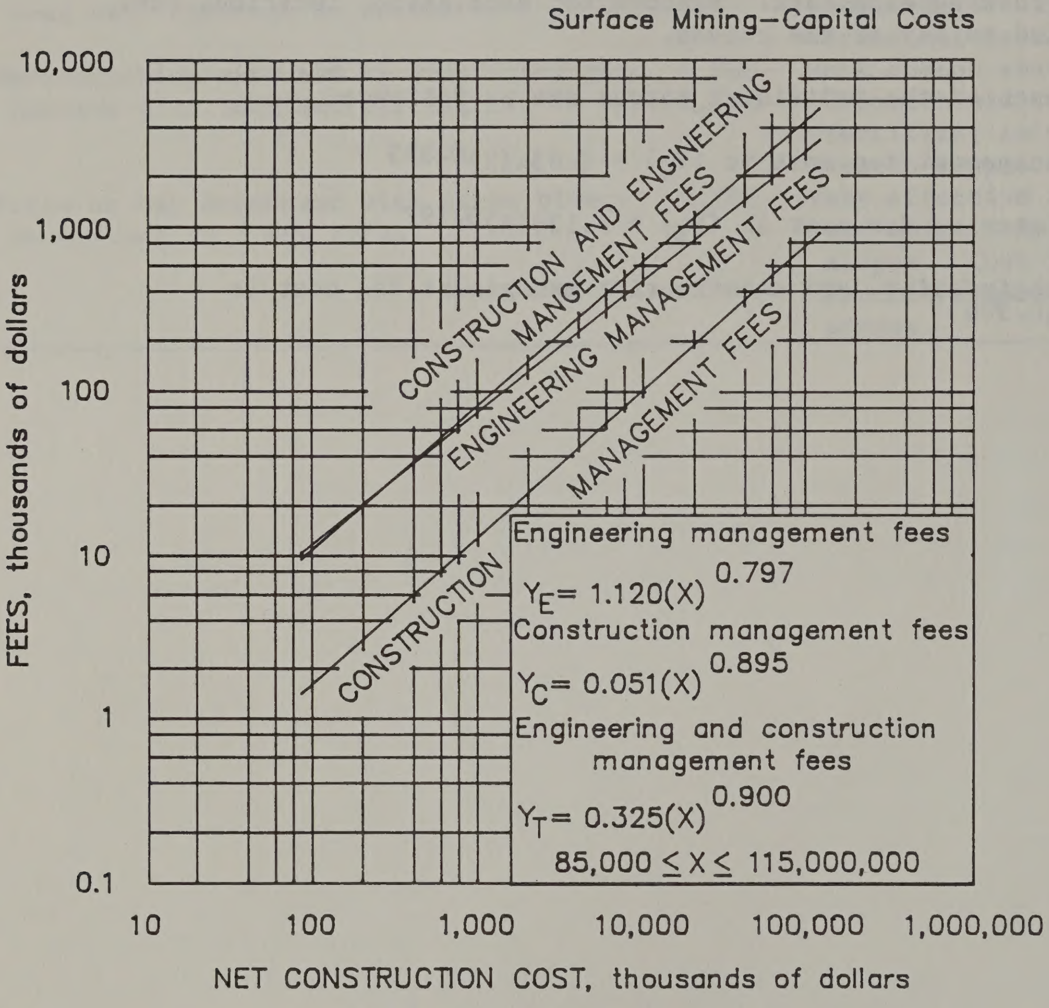
The engineering and construction management fees curves are based on the net constructed cost (X) for numerous projects of varying complexities. The net construction cost is the sum of the group cost for sections 2.2.1. (Preproduction Development), 2.2.2. (Mining Equipment), 2.2.3. (Transportation), 2.2.4. (Mine Plant General Operations), 2.2.6. (Infrastructure), and 2.2.7. (Restoration During Construction). The total engineering and construction management fee curve is based on a single firm performing both tasks. The other two curves are based on different firms performing each task. Factors for escalation, location, etc., should not be applied to any of the curves.

The equations for each of the individual curves are as follows:

The construction management fee cost is $(Y_C) = 0.051(X)^{0.895}$

The design and engineering fee cost is $(Y_E) = 1.120(X)^{0.797}$

The total design, engineering, and construction management fee cost is $(Y_T) = 0.325(X)^{0.900}$



2.2.8. Engineering and construction management fees

2.2. SURFACE MINING--CAPITAL COSTS

2.2.9. WORKING CAPITAL

Working capital is the cash required to sustain a mining and/or milling operation between mining the ore and receiving revenue from its sale. It is the capital required to meet out of pocket expenses, such as payroll, equipment operation, utilities, and administrative operating costs. In aggregate, these are the total operating costs for the operation during the designated time period. Because this time lag persists; that is, monies received in payment for September's production are reinvested in material and supplies to produce ore in November or December, a continuing account must be maintained as long as the operation is active.

A reasonable estimate of this lag period is dependent upon the type of operation under study. For operations that must send concentrates to a smelter, working capital is estimated as 10 weeks of operating, administrative, and transportation costs. This estimate includes Two weeks for transportation by rail to the smelter as well as two months for the smelter to make payment. By far the majority of precious and nonferrous metal producers can be thus classified.

Less working capital, 6 weeks of operating and administrative costs, is required for mines that market their product directly or that have vertically integrated processing facilities (i.e., same company owns smelter and/or refinery or company sells the end product).

ADJUSTMENT FACTORS

Adjustments should be considered if the transportation time to the smelter or smelter settlement time varies from assumed values. Adjustments should also be made to mine working capital if large mined ore stockpiles are maintained between the mining and milling stages, as this also advances the final settlement date.

For mines with mills that do not ship concentrates on a regular schedule because of remoteness and/or do not operate year-round, working capital should be increased appropriately.

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.1. CLEARING

The curve for clearing production is based on costs for medium light growth on terrain with a side slope of 20% to 50%. Estimate one tree, 0.33 m in diameter, per 40 m^2. The rate of clearing is determined by the surface mine production rate.

Total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a clearing rate of (X), in hectares per day. The curves are valid for operations between 0.1 and 10 ha/d, operating one shift per day. The curves include all daily operating and maintenance costs associated with clearing a land surface for further development.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 1{,}552.120(X)^{0.819}$

The operating labor costs are distributed as follows:

Direct labor...............	84%
Maintenance labor..........	16%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator............	21%	$16.33
Truck driver..............	6%	15.89
General laborer...........	73%	13.66

The average wage for labor is $14.28 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 245.963(X)^{0.953}$

The supply cost consists of 78% fuel oil and 22% tools, cables, and chokers for clearing operations of 0.1 to 5 ha/d. For clearing operations of 5 to 10 ha/d, the supply cost consists of 83% fuel oil (for burning trees and scrub) and 17% tools, cables, and chokers.

(E) Equipment Operating Cost $(Y_E) = 549.565(X)^{0.890}$

The equipment operating cost consists of

	Repair parts	Fuel and lube	Tires
Crawler dozers..........	51%	49%	-
Trucks, pickups, and chainsaws..........	14%	80%	6%

Equipment operating costs are based on a spread of 87% for crawler dozers and 13% for trucks, pickups, and chainsaws.

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factor:

Brush factor $(Y_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(Y_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain level to 20% side slope, multiply the costs obtained from the curves by the following factor:

Side slope factor $(F_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes from 50% to 100%, multiply the costs obtained from the curves by the following factor:

Side slope factor $(F_{S\ 50\%-100\%}) = 1.2$

On rocky slopes and slopes over 100%, multiply the costs obtained from the curves by the following factor:

Side slope factor $(F_{S\ +100\%}) = 2.5$

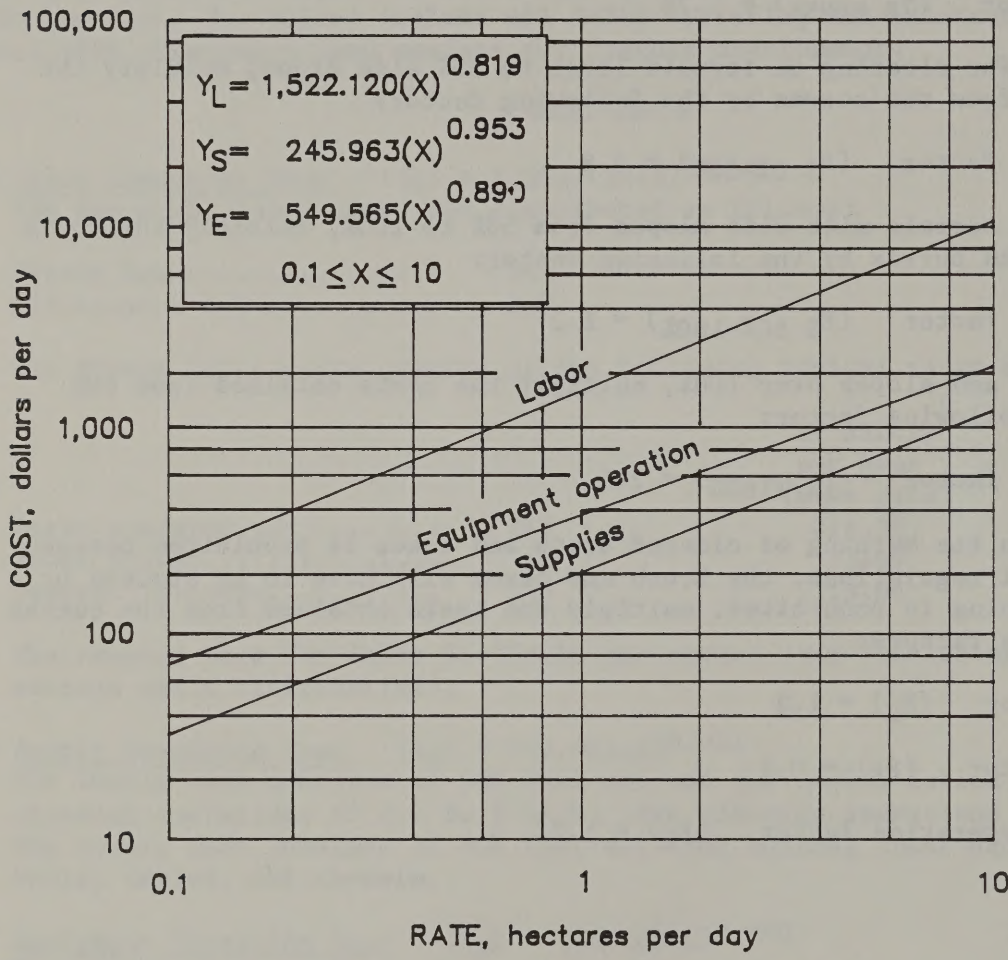
Burning Factor When the burning of cleared brush and trees is prohibited because of environmental regulations, the brush and trees will have to be stacked or buried. If burning is prohibited, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.2$

Supply factor $(F_S) = 0.2$

Equipment operation factor $(F_E) = 1.2$

Surface Mining—Operating Costs



3.2.1.1. Clearing

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.2. CORE DRILLING

Core drilling varies from nonexistent to extensive depending on many unknown factors. Core drilling is performed on centers varying from 30 to 245 m and to varying depths. The following tabulation gives the average range of cost for core diameter and depth of hole for drilling medium hard rocks. Costs could be higher or lower depending on hardness, location, access, and weather conditions.

Drilling cost, dollars per meter

Core		Drilling depth range, m			
Size	Diam, cm	0-150	150-300	300-450	450-600
PQ.......	8.49	$100-$115	$125-$138	NAp	NAp
NC.......	6.10	62- 79	69- 85	$90	$100
NX.......	5.40	59- 71	62- 75	80	90
BX.......	4.13	49- 64	52- 69	75	85
AX.......	2.86	43- 57	49- 62	70	80
EX.......	2.22	36- 52	43- 59	NAp	NAp

NAp Not applicable.

ADJUSTMENT FACTORS

Subcontractor Factor If drilling is accomplished by a drilling subcontractor, multiply cost by the following factor to compensate for subcontractor's markup.

Subcontractor factor $(F_S) = 1.1$

For additional details, see section 2.1.1. (Exploration).

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.3. DRILL AND BLAST OVERBURDEN AND WASTE

The curves have been developed in two parts. The total crawler-type percussion drill cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 1,000 and 8,000 mt, operating three shifts per day. The curves reflect costs for drilling 6-m-high benches with crawler-type percussion drills. Spacing of 2.5-in (6.35-cm) holes is on a pattern of 1.5 by 2 m to a depth of 7 m. The powder factor is 0.30 kg/mt.

The total daily rotary drill cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 8,000 and 300,000 mtpd, operating three shifts per day. Drilling is performed with rotary drills having a downpressure of from 13,600 to 56,700 kg. The powder factor varies from 0.11 to 0.20 kg/mt of waste with an average of 0.14 kg/mt of waste. Holes drilled average 12.25-in (31.12-cm) diameter from a range of 6- to 13.75-in (15.24- to 34.93-cm) diameter. Costs are based on drilling hard rocks with an average compressive strength (30,000 psi or 2,100 kg/cm^2). Bench heights are 12 to 18 m averaging 15 m. Drilling patterns and overdrilling varies with a range of 100 to 300 mt of blasted material per linear meter of drill hole. Secondary drilling and blasting varies from 0% to 10% of blasted material.

The curves include all daily operating and maintenance costs associated with drill and blast.

BASE CURVE

(L) Labor Operating Cost (Percussion Drill) $(Y_{L\ PERCUSSION}) = 1.747(X)^{0.909}$

The operating labor costs are distributed as follows:

Direct labor...............	76%
Maintenance labor..........	24%

The direct labor costs consist of the following typical range of personnel:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)	Av salary per hour (base rate)
Drilling crew...........	70%	83%	$15.22
Blasting crew...........	30%	17%	14.79

The average wage for labor is $15.84 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (Rotary Drill) $(Y_{L\ ROTARY}) = 0.042(X)^{1.035}$
The operating labor costs are distributed as follows:

Direct labor..............	43%
Maintenance labor.........	57%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Rotary and secondary drilling crews............	67%	$15.24
Blasting crew.............	33%	15.00

The average wage for labor is $15.45 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (Percussion Drill) $(Y_{S\ PERCUSSION}) = 30.278(X)^{0.504}$

The supply costs for percussion drill curve include drill bits and steel-related items and blasting supplies in the following cost proportions:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)
Drill bits and steel-related items.......	10%	25%
Blasting supplies..........	90%	75%

(S) Supply Operating Cost (Rotary Drill) $(Y_{S\ ROTARY}) = 0.147(X)^{0.984}$
The supply costs for rotary drill curve include drill bits and steelrelated items and blasting supplies in the following cost proportions:

	Small (8,000 to 100,000 mtpd)	Large (100,000 to 300,000 mtpd)
Drill bits and steel-related items.......	26%	16%
Blasting supplies..........	74%	84%

(E) Equipment Operating Cost (Percussion Drill) $(Y_{E\ PERCUSSION}) = 1.771(X)^{0.818}$

The equipment operating costs for percussion drill and blast are 86% for drilling equipment and 14% for trucks. The equipment operating cost includes power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Drill equipment.........	58%	42%	-
Trucks..................	8%	87%	5%

(E) Equipment Operating Cost (Rotary Drill) $(Y_{E\ ROTARY}) = 0.0294(X)^{1.057}$

The equipment operating costs for rotary drill and blast are 95% for drilling equipment and 5% for supporting equipment. The equipment operating cost includes power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires	Power
Drill equipment.......	79%	10%	-	11%
Trucks................	11%	80%	9%	-

ADJUSTMENT FACTOR

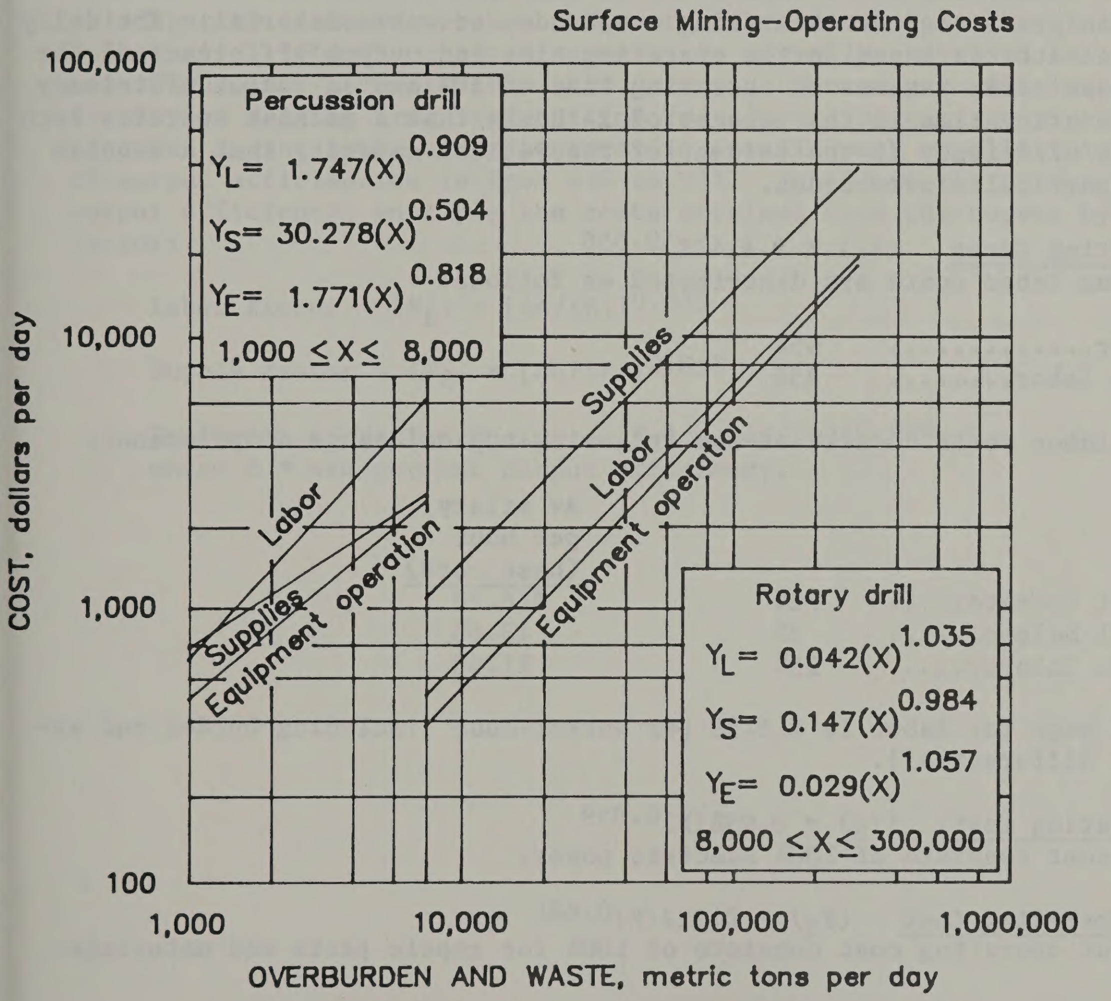
Drill and Blast Factor (D & B Factor) The curves indicate average costs for a wide range of materials as can be noted by drill sizes, bit sizes, powder factors, and drill pattern. To determine drilling and blasting costs, consideration must be given to material hardness, abrasiveness, natural fractures and jointing, and maximum-size fragments that can be loaded, hauled, and processed.

For favorable drilling conditions, multiply the costs obtained from the curves by the following factor:

D & B factor $(F_{D\ GOOD}) = 0.6$

Where the drilling conditions are unfavorable, multiply the costs obtained from the curves by the following factor:

D & B factor $(F_{D\ SEVERE}) = 2.0$



3.2.1.3. Drill and blast
DRILLS

3.2. SURFACE MINING - OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.1. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE BUCKET WHEEL EXCAVATION

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 2,200 and 125,000 mtpd, operating three shifts per day. The costs include only the operation of the bucket wheel excavator.

BASE CURVES

The base curve is predicated on excavating overburden or waste material. The daily output of an excavator is based on the operating time and output efficiency of the machine. The base curve assumes an operating time of 50% and an output efficiency of 46%. The operating time is the percent of 24 hours that a machine operates each day. The output efficiency is the percent of theoretical capacity that a machine delivers for a particular overburden.

(L) Labor Operating Curve $(Y_L) = 7.414(X)^{0.556}$

The operating labor costs are distributed as follows:

Direct labor.............	65%
Maintenance labor........	35%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Bucket wheel operator....	72%	$16.78
Bucket wheel helper......	3%	13.66
Bucket wheel laborer.....	25%	11.68

The average wage for labor is $15.58 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.058(X)^{0.859}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.212(X)^{0.681}$

The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Shift Adjustment The curve is based on a three-shift-per-day operation. Typically bucket wheel excavators are run continuously. For a oneor two-shift operation, decrease the operating costs proportionately.

Operating Time Factor The base case assumes a 50% operating time. Bucket wheel excavators do not have high availabilities. The range of expected operating time is 41% to 60%. To adjust the base case for different operating times, multiply the cost obtained from the labor curve by the following factor:

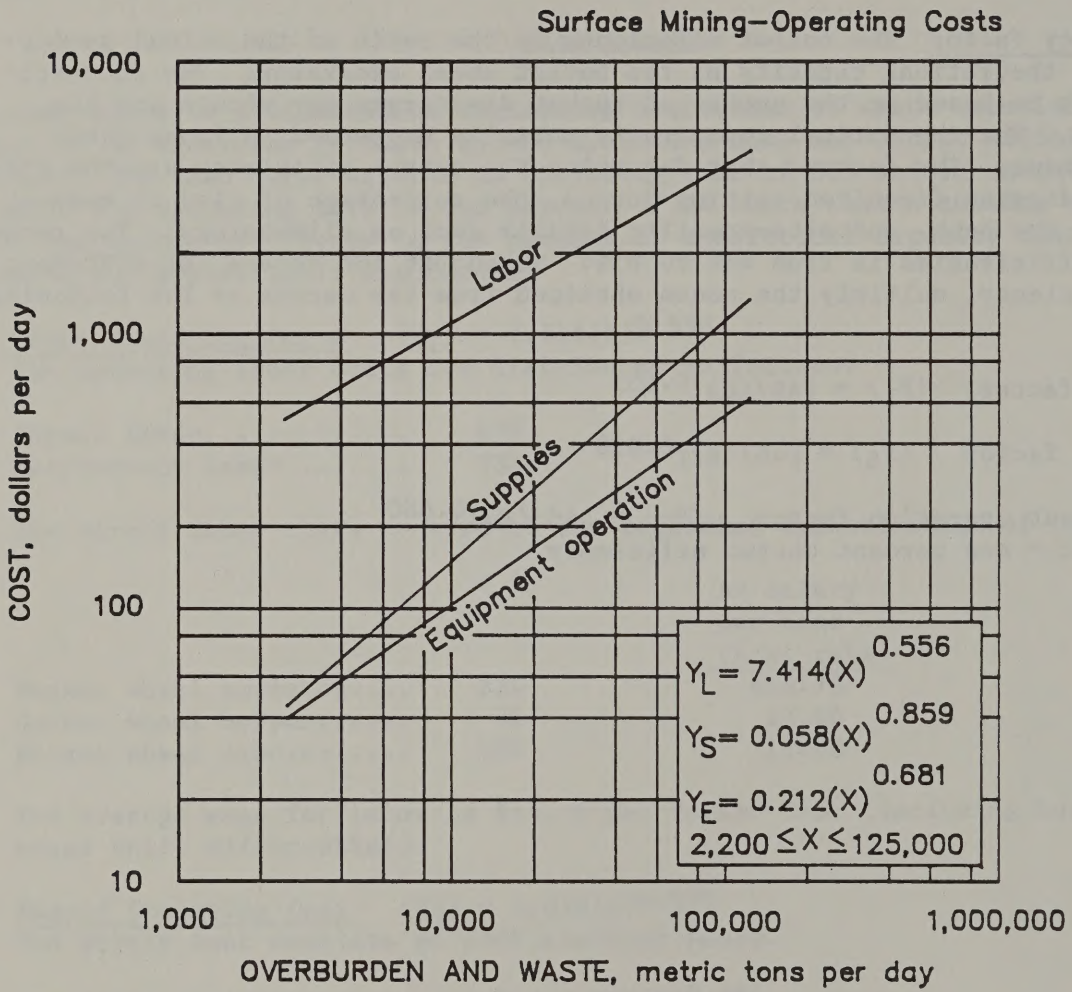
Labor factor $(F_L) = [50/(P)]^{0.554}$
where P = new percent operating time.

Output Efficiency Factor The output efficiency is the ratio of the actual production to the theoretical capacity of the bucket wheel excavator. The theoretical capacity is based on the number of bucket discharges per minute and the bucket size. The theoretical capacity is normally expressed in loose cubic meters per hour. The factors that determine the output efficiency are the difficulty of digging (required cutting force), the percentage of clay or compact material in the bank, and site-specific details such as climatology. The range of output efficiencies is from 44% to 85%. To adjust the curves for different output efficiency, multiply the costs obtained from the curves by the following factor:

Labor factor $(F_L) = [46/(E)]^{0.555}$

Supply factor $(F_S) = [46/(E)]^{0.858}$

Equipment operation factor $(F_E) = [46/(E)]^{0.680}$
where E = new percent output efficiency.



Surface Mining—Operating Costs

3.2.1.4.1. Excavation, load and haul
BUCKET WHEEL EXCAVATION

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.2. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE DRAGLINES

The curve for draglines covers excavating and casting a medium-digging overburden and waste material from a dry pit into a spoil pile. The material is assumed to weigh 2.0 mt/m^3 for crawler (diesel-powered) draglines and 1.5 mt/m^3 for walking (electric-powered) draglines.

Crawler draglines range in size from 2- to 20-yd^3 capacity; walking draglines, from 16- to 50-yd^3 capacity. One dozer is provided for each dragline operation for cleanup and support.

The total daily crawler dragline cost is the sum of two separate cost curves (labor and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 2,000 and 15,000 mtpd, operating one shift per day. The total daily walking dragline cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 15,000 and 150,000 mt, operating three shifts per day. The curves include all daily operating and maintenance costs associated with dragline excavation.

BASE CURVE

(L) Labor Operating Cost (crawler dragline) $(Y_{L\ CRAWLER}) = 43.884(X)^{0.363}$
The operating labor costs are distributed as follows:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)
Direct labor...............	59%	56%
Maintenance labor..........	41%	44%

The direct labor costs consist of the following typical range of personnel:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)	Av salary per hour (base rate)
Crawler dragline operator..	41%	26%	$18.11
Oiler......................	24%	22%	15.89
Dozer operator.............	25%	23%	16.33
Utility operator...........	10%	29%	13.66

The average wage for labor is $16.13 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (walking dragline) $(Y_{L\ WALKING}) = 12.249(X)^{0.542}$
The operating labor costs are distributed as follows:

Direct labor..............	62%
Maintenance labor.........	38%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Walking dragline operator..	30%	$18.11
Oiler.....................	26%	15.89
Dozer operator............	27%	16.33
Utility operator..........	17%	13.66

The average wage for labor is $16.46 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (walking dragline) $(Y_{S\ WALKING}) = 0.0395(X)^{1.003}$
The supply cost consists of 100% electric power for the walking (electric) draglines.

(E) Equipment Operating Cost (crawler dragline) $(Y_{E\ CRAWLER}) = 2.218(X)^{0.688}$
The equipment operating cost for crawler draglines consists of 70% for the dragline and 30% for support equipment consisting of 25% crawler tractors and 5% pickup trucks.

(E) Equipment Operating Cost (walking dragline) $(Y_{E\ WALKING}) = 0.533(X)^{0.834}$
The equipment operating cost for walking draglines consists of 66% for the dragline and 34% for support equipment consisting of 31% crawler tractors and 3% pickup trucks.

The general equipment operating cost distribution for draglines and support equipment is as follows:

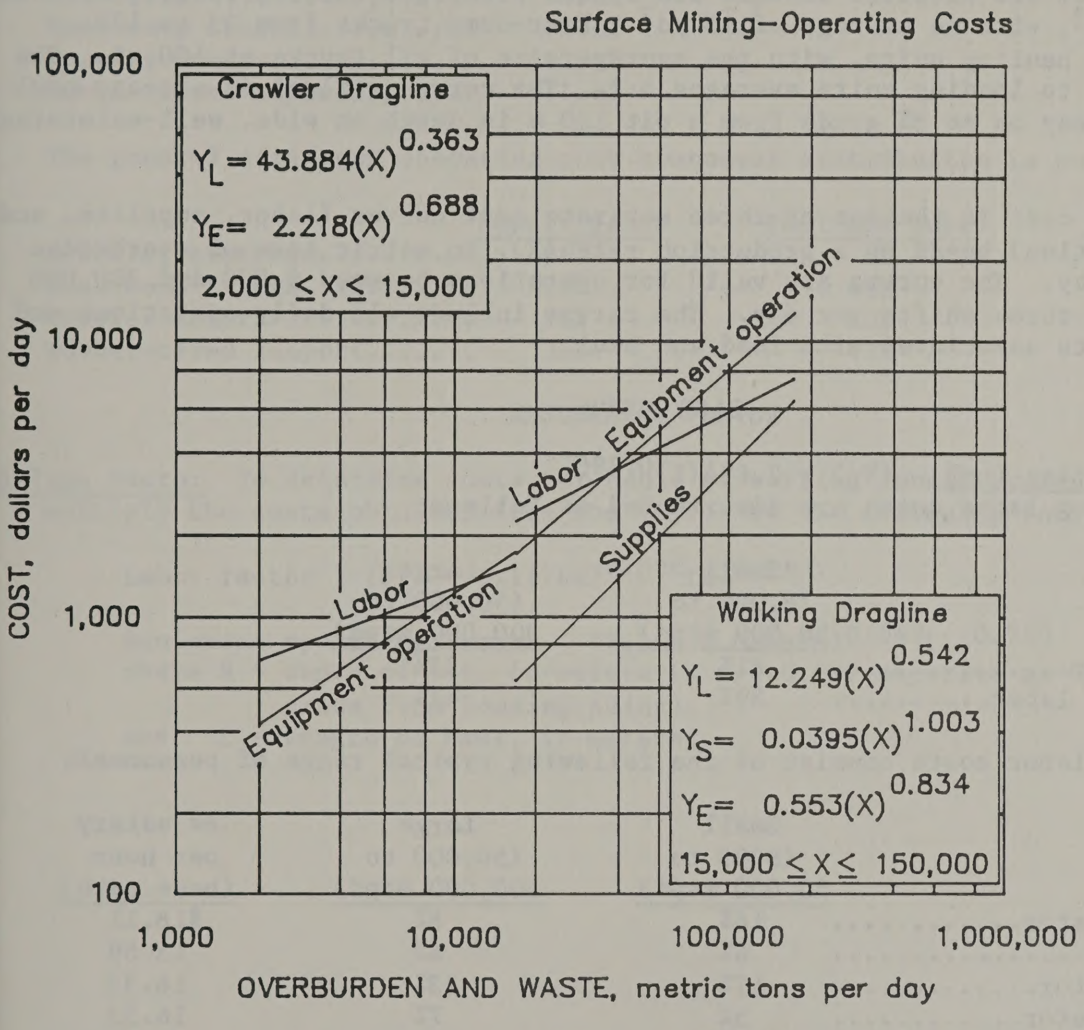
	Repair parts	Fuel and lube	Tires
Walking draglines..........	94%	6%	-
Crawler draglines..........	65%	35%	-
Crawler dozers.............	49%	51%	-
Rubber-tired support.......	8%	90%	2%

ADJUSTMENT FACTORS

To determine the cost of a crawler dragline operation loading to trucks, use the values obtained from the electric shovels and trucks curve. Adjust the values by increasing each curve component 25% and combine equipment operation and supplies curve to account for the substitution of diesel fuel for electric power. (NOTE--Supplies values for the electric shovels and trucks curve include only electric power.)

LIMITATIONS OF DRAGLINE EXCAVATION CURVES

The cost curves for draglines are very general and are meant to represent a typical excavating operation. Factors that greatly affect dragline excavation costs include the swing angle of boom and hoisting height.



3.2.1.4.2. Excavation, load and haul
DRAGLINES

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.3. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE ELECTRIC SHOVEL AND TRUCKS

The curves show the cost per day for excavating, loading, and hauling both common and shot rock. For common earth excavation, 1 bank m^3 equals 2.08 mt; for shot rock, 1 bank m^3 equals 2.61 mt.

The loading units are electric shovels and diesel front-end loaders ranging in size from 5 to 30 yd^3, with an average of 15 yd^3. Rear-dump trucks from 35 to 170 st are the main hauling units, with the average size of all trucks at 100 st. The ratio of trucks to loading units averages 6:1. The curves reflect an average haul of 2,000 m one-way on an 8% grade from a pit 120 m in depth on wide, well-maintained roads.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 8,000 and 300,000 mtpd, operating three shifts per day. The curves include all daily operations and maintenance costs associated with load and haul.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2.694(X)^{0.790}$

The operating labor costs are distributed as follows:

	Small (8,000 to 50,000 mtpd)	Large (50,000 to 300,000 mtpd)
Direct labor...............	61%	53%
Maintenance labor..........	39%	47%

The direct labor costs consist of the following typical range of personnel:

	Small (8000 to 50,000 mtpd)	Large (50,000 to 300,000 mtpd)	Av salary per hour (base rate)
Shovel operator............	14%	8%	$18.11
Oiler......................	6%	4%	15.89
Dozer operator.............	17%	23%	16.33
Grader operator............	5%	7%	16.33
Front-end loader operator..	3%	1%	16.33
Truck driver...............	52%	57%	15.89
General laborer............	3%	-	13.66

The average wage for labor is $16.54 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.188(X)^{0.780}$
The supply cost consists of 100% electric power for the walking (electric) draglines.

(E) Equipment Operating Cost $(Y_E) = 1.850(X)^{0.867}$
The equipment operating cost covers the daily operating cost for all excavation, loading, and hauling equipment and includes allowances for repair parts, tires, lubrication, and fuel consumption.

The equipment operating cost distribution for a shovel and truck operation is

Shovels....................	7.0%
Rear-dump trucks...........	70.0%
Crawler dozers.............	12.0%
Rubber-tired support.......	11.0%

The general equipment operating cost component distribution is as follows:

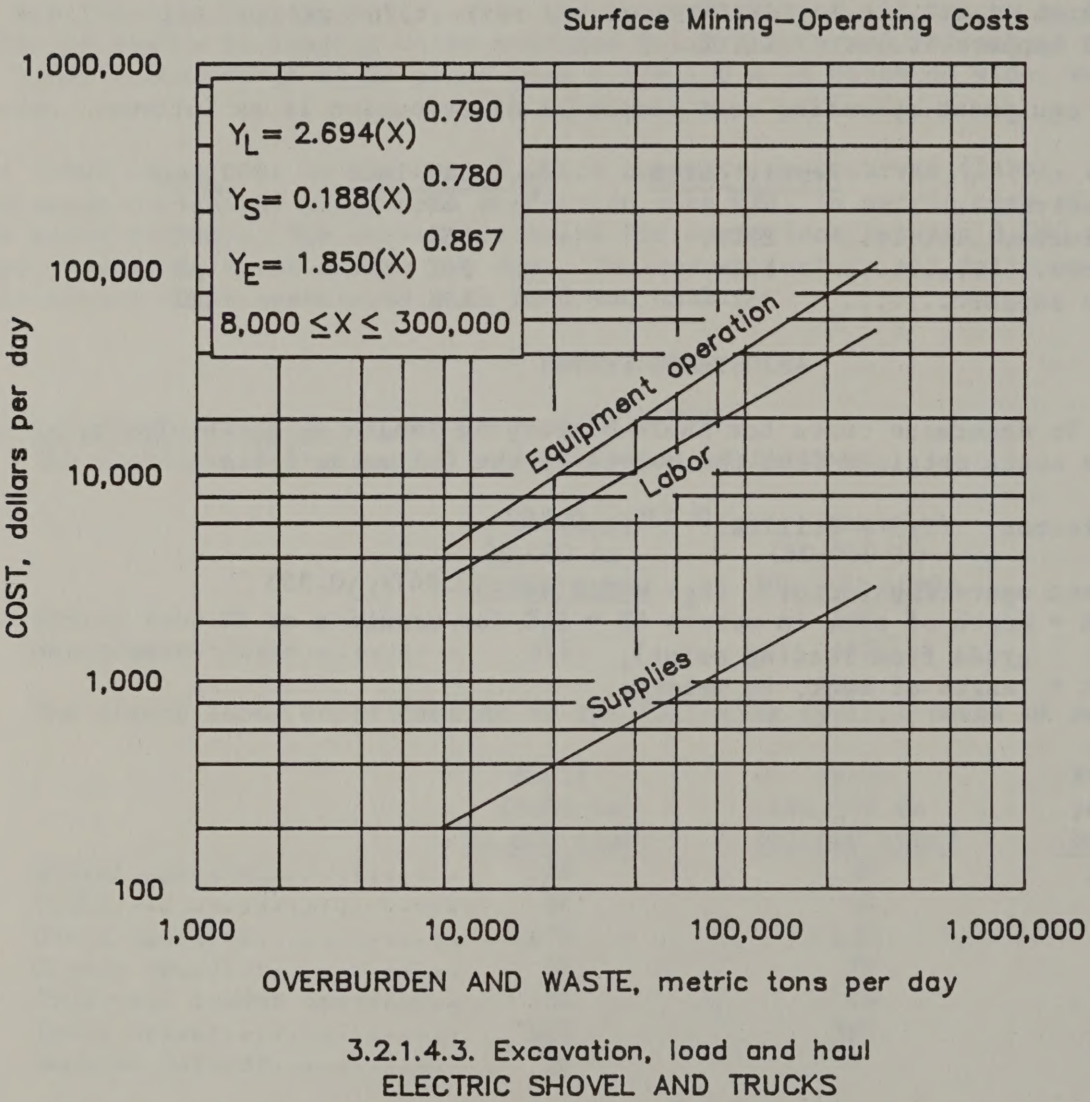
	Repair parts	Fuel and lube	Tires
Shovels, electric..........	96%	4%	-
Rear-dump trucks...........	25%	48%	27%
Crawler dozers.............	50%	50%	
Rubber-tired support.......	35%	47%	18%

ADJUSTMENT FACTOR

Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.117(R)^{0.030}(L)^{0.263}$

Equipment operating factor $(F_E) = 0.0546(R)^{0.047}(L)^{0.353}$
where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),
and L = length of haul, in meters.



3.2.1.4.3. Excavation, load and haul
ELECTRIC SHOVEL AND TRUCKS

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.4. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

The curve shows the cost per day for loading and hauling both common and shot rock. For common earth excavation, 1 bank m^3 equals 2.08 mt; for shot rock, 1 bank m^3 equals 2.61 mt.

The costs are based on mines using front-end loaders or diesel shovels for loading and trucks for haulage. The loaders and shovels range in size from 1 to 6 yd^3 and the trucks range from 10 to 35 st. The curves reflect an average haul of 750 m one way on an 8% grade from a pit 60 m deep.

The total daily cost is the sum of two separate cost curves (labor and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 1,000 and 10,000 mtpd, operating two shifts per day. The curves include all daily operating and maintenance costs associated with excavation, loading, and haulage.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 37.003(X)^{0.529}$

The operating labor costs are distributed as follows:

Direct labor...............	70%
Maintenance labor..........	30%

The direct labor costs consist of the following typical range of personnel:

	Small (1,000 to 3,000 mtpd)	Large (3,000 to 10,000 mtpd)	Av salary per hour (base rate)
Loader-shovel crew.........	30%	21%	$16.24
Truck haulage crew.........	46%	37%	15.89
Dozer operator.............	24%	17%	16.33
Rubber-tired support crew......................	-	25%	16.11

The average wage for labor for small operations is $16.20 per worker-hour (including burden and average shift differential).

The average wage for labor for large operations is $16.42 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 24.620(X)^{0.576}$

The equipment operating cost distribution for front-end loader-diesel shovel and truck operation is

Front-end loader-shovel....	18%
Rear-dump truck............	43%
Crawler dozer..............	23%
Rubber-tired support.......	16%

The general equipment cost component distribution is as follows:

	Repair parts	Fuel and lube	Tires
Shovel, diesel.............	70%	30%	-
Front-end loader...........	33%	44%	23%
Rear-dump truck............	28%	52%	20%
Crawler dozer..............	51%	49%	-
Rubber-tired support.......	28%	63%	9%

ADJUSTMENT FACTOR

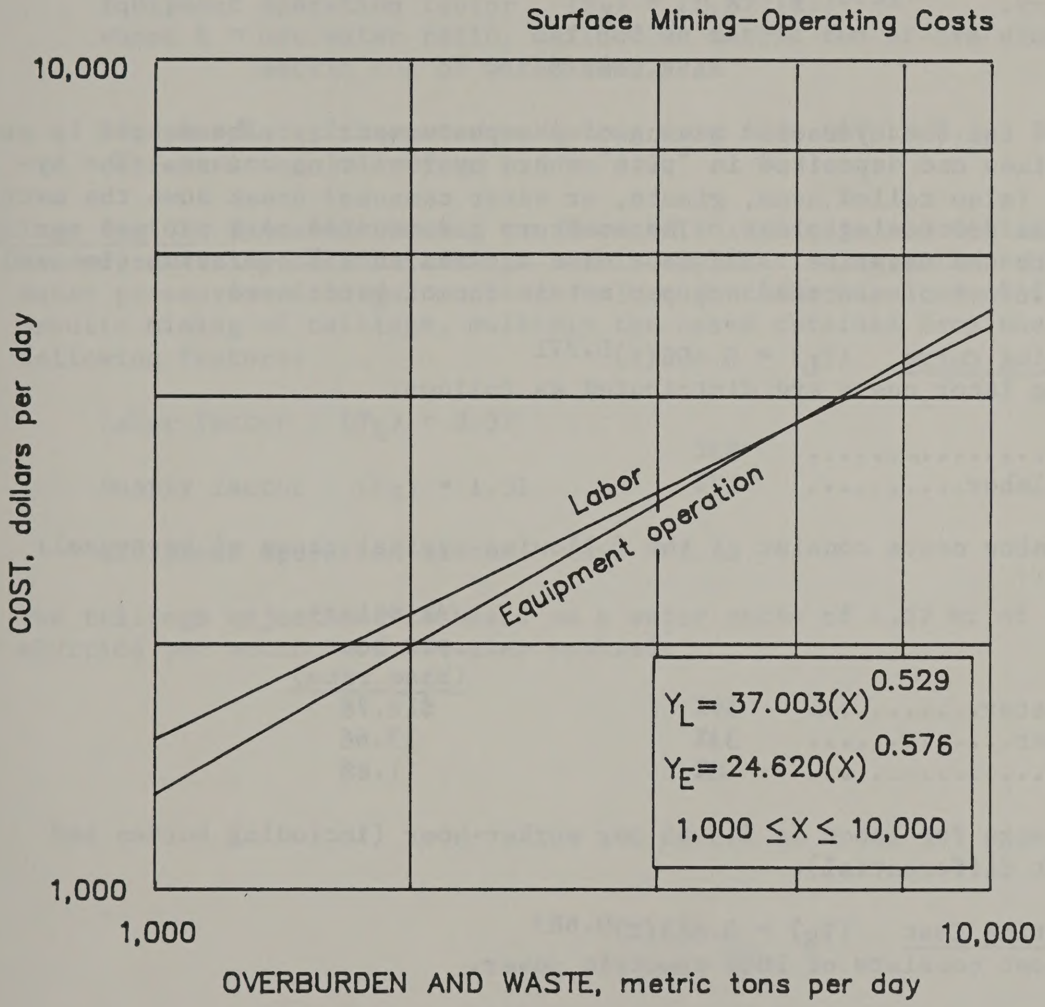
Haulage Factor To determine costs for hauls of varying haul length or depth of pit multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.155(R)^{0.030}(L)^{0.263}$

Equipment operation factor $(F_E) = 0.080(R)^{0.047}(L)^{0.353}$

where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),

and L = length of haul, in meters.



3.2.1.4.4. Excavation, load and haul
FRONT–END LOADER OR DIESEL SHOVEL AND TRUCKS

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.5. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE HYDRAULIC MINING

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of material slurried per day. The curves are valid for operations between 9,500 and 58,000 mtpd, operating three shifts per day. The costs include the operation of the monitors and high pressure water pumps. Not included in the estimates is the cost for pumping the slurry.

BASE CURVES

The base curve is for the hydraulic mining of phosphate matrix. The matrix is excavated by draglines and deposited in "pits" where hydraulicing occurs. The hydraulic monitors (also called guns, giants, or water cannons) break down the matrix for pumping to the processing plant. The monitors are mounted on a pit gun car that advances with the dragline. The base case assumes an 85% operating time and a water ratio of 0.67 mt of slurried ore per metric ton of water used.

(L) Labor Operating Curve $(Y_L) = 0.406(X)^{0.771}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Monitor operator...........	59%	$16.78
Monitor helper.............	33%	13.66
Laborer....................	8%	11.68

The average wage for labor is $15.65 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.883(X)^{0.685}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.019(X)^{0.748}$
The equipment operating cost consists of 100% for monitor repair parts and materials. The repair costs are divided 30% for water pumps and 70% for the monitor systems (hydraulic pumps, controls, and monitors).

ADJUSTMENT FACTORS

Water Ratio Each deposit to be hydraulically mined will require different quantities of water, and therefore, different sizes or numbers of monitors. The more competent (tougher) the deposit, the more water that will be required. The measure of difficulty in slurrying the deposit is the mass ratio of ore excavated to water used. To adjust the base curves for different water requirements, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [0.67/(R)]^{0.050}$

Supply factor $(F_S) = [0.67/(R)]^{1.285}$

Equipment operation factor $(F_E) = [0.67/(R)]^{0.327}$
where R = new water ratio, defined as metric ton of ore slurried per metric ton of water used.

For phosphate, the water ratio can vary from 0.7 to 0.3. For other applications it can vary from 1.5 to 0.2.

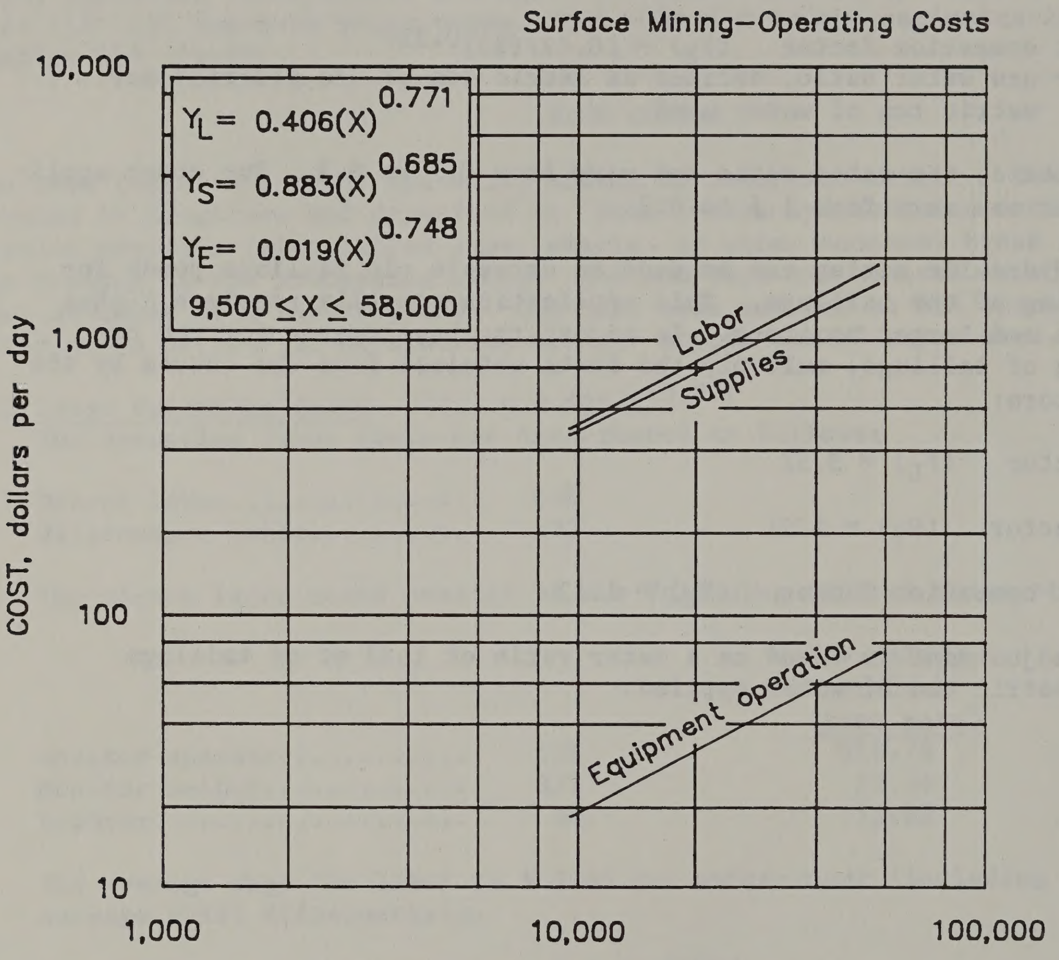
Tailings Factor Hydraulic mining can be used to excavate old tailings ponds for the reprocessing of the tailings. This application normally requires higher water pressure and larger monitors. To adjust the base curves for the hydraulic mining of tailings, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 3.32$

Supply factor $(F_S) = 1.51$

Equipment operation factor $(F_E) = 1.12$

The tailings adjustment is based on a water ratio of 1.22 mt of tailings slurried per metric ton of water applied.



3.2.1.4.5. Excavation, load and haul
HYDRAULIC MINING

3.2. SURFACE MINING--OPERATING COSTS

3.2.1. PRODUCTION DEVELOPMENT

3.2.1.4.6. EXCAVATION, LOAD AND HAUL OVERBURDEN AND WASTE SCRAPERS

The curves show the cost per day for loading and hauling unconsolidated overburden. Scraper production in metric tons per day is based on an assumed material having a weight of 2.2 mt/m^3 and requiring ripping.

The costs cover wheel tractor scrapers ranging in size and type from 150-hp self-loading elevating scrapers to 550-hp twin-engine scrapers. The curves are based on a one-way haul of 900 m on a level grade and include a 6% rolling resistance in the pit area.

The total daily cost is the sum of two separate cost curves (labor and equipment operation) based on a production rate (X), in metric tons of overburden and waste per day. The curves are valid for operations between 2,000 and 300,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with load and haul.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 3.825(X)^{0.735}$

The operating labor costs are distributed as follows:

Direct labor...............	53%
Maintenance labor..........	47%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Scraper operator...............	58%	$16.33
Crawler operator...............	32%	16.33
Rubber-tired support operator..	10%	16.11

The average wage for labor is $16.64 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 0.602(X)^{0.925}$

The equipment operating cost distribution for a scraper operation is

Scraper.....................	71%
Crawler-dozer..............	24%
Rubber-tired support.......	5%

The general equipment cost component distribution is as follows:

	Repair parts	Fuel and lube	Tires
Scraper....................	38%	47%	15%
Crawler-dozer..............	53%	47%	-
Rubber-tired support.......	36%	52%	12%

ADJUSTMENT FACTORS

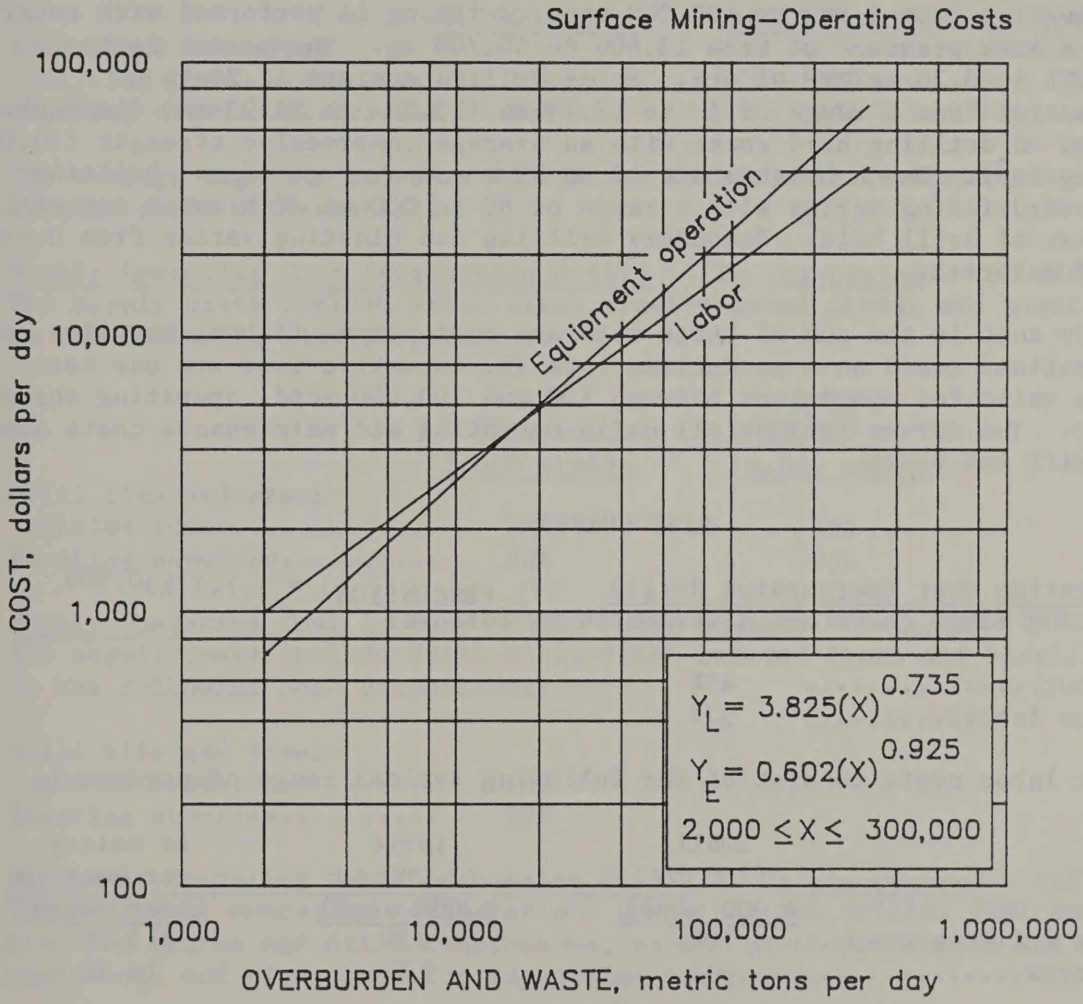
Haulage Factor To determine costs for varying haul lengths and grades, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.087(L)^{0.359}(G)^{1.530}$

Equipment operation factor $(F_E) = 0.064(L)^{0.403}(G)^{1.620}$
where L = length of haul, in meters,
and G = grade [defined as 1.0 plus or minus (percent grade/100)].

Ripping Factor If no ripping is required, multiply the costs obtained from the curves by the following factor:

Ripping factor $(F_R) = 0.85$



3.2.1.4.6. Excavation, load and haul
SCRAPERS

3.2. SURFACE MINING - OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.1 DRILL AND BLAST ORE
DRILLS

The curves have been developed in two parts. For mines excavating from 100 to 8,000 mtpd ore , the curves reflect costs for drilling 6-m high benches with crawler-type percussion drills. Spacing of 2.5-in holes is on a pattern of 1.5 by 2 m to a depth of 7 m. The powder factor is 0.30 kg/mt^3.

For mines excavating from 8,000 to 100,000 mtpd, drilling is performed with rotary drills having a down pressure of from 13,600 to 56,700 kg. The powder factor varies from 0.11 to 0.20 kg/mt^3 of ore. Holes drilled average 12.25-in (31.12-cm) diameter from a range of 6- to 13.75-in (15.24- to 34.93-cm) diameter. Costs are based on drilling hard rocks with an average compressive strength (30,000 psi or 2,100 kg/cm^2). Bench heights are 12 to 18 m and average 15 m. Drilling patterns and overdrilling varies with a range of 80 to 200 mt of blasted material per linear meter of drill hole. Secondary drilling and blasting varies from 0 to 10% of blasted material.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X) in metric tons ore per day. The curves are valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with drill and blast.

BASE CURVE

(L) Labor Operating Cost (percussion drill) $(Y_{L\ PERCUSSION}) = 1.747(X)^{0.909}$
The operating labor costs are distributed as follows:

Direct labor...............	43%
Maintenance labor..........	57%

The direct labor costs consist of the following typical range of personnel:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)	Av salary per hour (base rate)
Percussion drilling crew...	70%	83%	$15.22
Blasting crew..............	30%	17%	14.79

The average wage for labor is $15.41 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (rotary drill) $(Y_{L\ ROTARY}) = 0.720(X)^{0.779}$
The operating labor costs are distributed as follows:

	Small (8,000 to 30,000 mtpd)	Large (30,000 to 100,000 mtpd)
Direct labor...............	53%	47%
Maintenance labor..........	47%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (8,000 to 30,000 mtpd)	Large (30,000 to 100,000 mtpd)	Av salary per hour (base rate)
Rotary and secondary drilling crew.............	70%	65%	$15.29
Blasting crew..............	30%	35%	15.15

The average wage for labor is $15.56 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (percussion drill) $(Y_{S\ PERCUSSION}) = 30.278(X)^{0.504}$
The supply costs include drill bits, steel-related items, and blasting supplies in the following cost proportions:

	Small (100 to 3,000 mtpd)	Large (3,000 to 8,000 mtpd)
Drill bits and steel-related items.............	10%	25%
Blasting supplies..........	90%	75%

(S) Supply Operating Cost (rotary drill) $(Y_{S\ ROTARY}) = 0.152(X)^{0.985}$
The supply costs include drill bits, steel-related items and blasting supplies in the following cost proportions:

Drill bits and steel-related items.............	18%
Blasting supplies..........	82%

(E) Equipment Operating Cost (percussion drill) $(Y_{E\ PERCUSSION}) = 1.771(X)^{0.818}$
The equipment operating costs include power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating costs for percussion drill and blast consist of 86% for drilling equipment and 14% for trucks. Drilling equipment costs include 58% for repair parts and 42% for fuel and lubrication. Supporting equipment costs include 87% for fuel and lubrication, 8% for repair parts, and 5% for tires.

(E) Equipment Operating Cost (rotary drill) $(Y_{E\ ROTARY}) = 0.614(X)^{0.783}$
The equipment operating costs include power for the drills, fuel and lubrication for trucks and drill compressors, repair parts for drills and supporting equipment, and tire costs for supporting equipment.

The equipment operating costs for rotary drill and blast consist of 91% for drilling equipment and 9% for supporting equipment. Rotary drilling equipment operating costs include 77% for repair parts, 12% for fuel and lubrication, and 11% for power. Supporting equipment costs include 76% for fuel and lubrication, 17% for repair parts, and 7% for tires.

ADJUSTMENT FACTOR

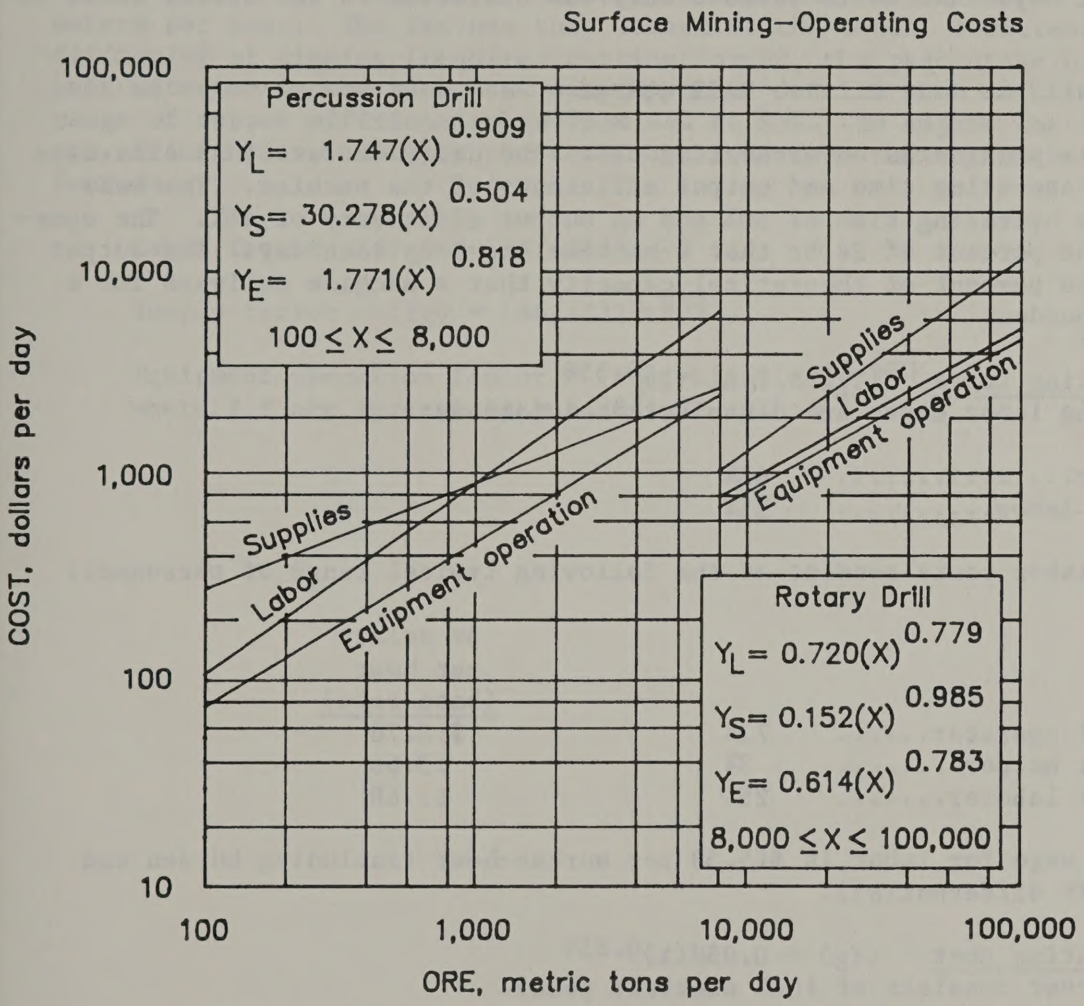
Drill and Blast Factor (D & B Factor) The curves indicate average costs for a wide range of materials as can be noted by drill sizes, bit sizes, powder factors, and drill pattern. To determine drilling and blasting costs, consideration must be given to material hardness, abrasiveness, natural fractures and jointing, and maximum-size fragments that can be loaded, hauled, and processed.

For favorable conditions, multiply the costs obtained from the curves by the following factor:

D & B factor $(F_{D\ GOOD}) = 0.6$

Where the above conditions are unfavorable, multiply the costs obtained from the curves by the following factor:

D & B factor $(F_{D\ SEVERE}) = 2.0$



3.2.2.1. Drill and blast
DRILLS

3.2. SURFACE MINING--OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.2. EXCAVATION, LOAD AND HAUL ORE
BUCKET WHEEL EXCAVATION

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X) in metric tons ore per day. The curves are valid for operations between 2,200 and 125,000 mtpd, operating three shifts per day. The costs include only the operation of the bucket wheel excavator.

BASE CURVES

The base curve is predicated on excavating ore. The daily output of an excavator is based on the operating time and output efficiency of the machine. The base curve assumes an operating time of 50% and an output efficiency of 46%. The operating time is the percent of 24 hr that a machine operates each day. The output efficiency is the percent of theoretical capacity that a machine delivers for a particular overburden.

(L) Labor Operating Curve $(Y_L) = 7.414(X)^{0.556}$

The operating labor costs are distributed as follows:

Direct labor...............	65%
Maintenance labor..........	35%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Bucket wheel operator......	72%	$16.78
Bucket wheel helper........	3%	13.66
Bucket wheel laborer.......	25%	11.68

The average wage for labor is $15.58 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.058(X)^{0.859}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.212(X)^{0.681}$

The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Shift Adjustment The curve is based on a three-shift-per-day operation. Typically, bucket wheel excavators are run continuously. For a oneor two-shift operation, decrease the operating costs proportionately.

Operating Time Factor The base case assumes a 50% operating time. Bucket wheel excavators do not have high availabilities. The range of expected operating time is 41% to 60%. To adjust the base case for different operating times, multiply the the cost obtained from the labor curve by the following factor:

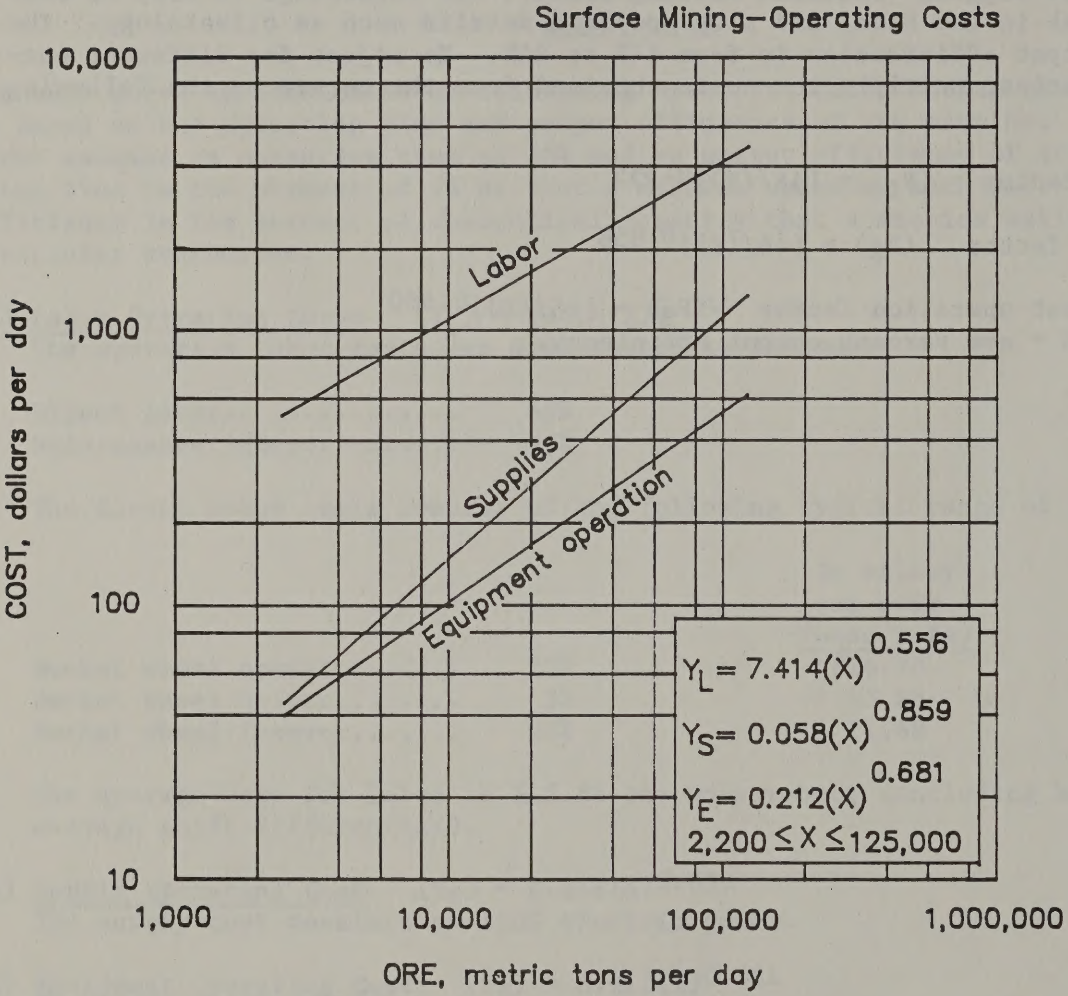
Labor factor $(F_L) = = [50/(T)]^{0.554}$
where T = new percent operating time.

Output Efficiency Factor The output efficiency is the ratio of the actual production to the theoretical capacity of the bucket wheel excavator. The theoretical capacity is based on the number of bucket discharges per minute and the bucket size. The theoretical capacity is normally expressed in loose cubic meters per hour. The factors that determine the output efficiency are the difficulty of digging (required cutting force), the percentage of clay or compact material in the bank, and site-specific details such as climatology. The range of output efficiencies is from 44% to 85%. To adjust for different output efficiencies, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [46/(E)]^{0.555}$

Supply factor $(F_S) = [46/(E)]^{0.858}$

Equipment operation factor $(F_E) = [46/(E)]^{0.680}$
where E = new percent output efficiency.



3.2.2.2. Excavation, load and haul
BUCKET WHEEL EXCAVATION

3.2. SURFACE MINING--OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.3. EXCAVATION, LOAD AND HAUL ORE DRAGLINE

The curve for draglines covers excavating and casting a medium-digging ore from a dry pit into a spoil pile. The material is assumed to weigh 2.0 mt/m^3 for crawler (diesel-powered) draglines and 1.5 mt/m^3 for walking (electric-powered) draglines.

Crawling draglines range in size from 2.0- to 20-yd^3 capacity; walking draglines, from 16 to 50 cubic-yard capacity. One dozer is provided for each dragline operation for cleanup and support.

The total daily cost for crawler draglines is the sum of the two separate cost curves (labor and equipment operation) and for walking draglines is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X) in metric tons of ore per day. The curve for crawler draglines is valid for a production range of 2,000 to 15,000 mtpd, operating one shift per day; for walking draglines, the curves are valid for a production range of 15,000 to 150,000 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost (crawler dragline) $(Y_{L\ CRAWLER}) = 43.884(X)^{0.363}$

The operating labor costs are distributed as follows:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)
Direct labor...............	59%	44%
Maintenance labor..........	41%	56%

The direct labor costs consist of the following typical range of personnel:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 15,000 mtpd)	Av salary per hour (base rate)
Dragline operator..........	41%	26%	$18.11
Oiler......................	24%	22%	15.89
Dozer operator.............	25%	23%	16.33
Utility operator...........	10%	29%	13.66

Labor costs average $16.13 per worker-hour (including burden and average shift differential).

(L) Labor Operating Cost (walking dragline) $(Y_{L\ WALKING}) = 12.249(X)^{0.542}$
The operating labor costs are distributed as follows:

Direct labor...............	62%
Maintenance labor..........	38%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dragline operator..........	30%	$18.11
Oiler......................	26%	15.89
Dozer operator.............	27%	16.33
Utility operator...........	17%	13.66

Labor costs average $16.46 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (walking dragline) $(Y_{S\ WALKING}) = 0.0395(X)^{1.003}$
The supply cost consists of 100% electric power for the electric draglines.

(E) Equipment Operating Cost (crawler dragline) $(Y_{E\ CRAWLER}) = 2.218(X)^{0.688}$
The equipment cost distribution for crawler draglines is 70% for the dragline and 30% for support equipment consisting of 25% for crawler tractors and 5% for pickup trucks.

(E) Equipment Operating Cost (walking dragline) $(Y_{E\ WALKING}) = 0.533(X)^{0.834}$
The equipment operating cost distribution for walking draglines is 66% for the dragline and 34% for support equipment consisting of 31% for crawler tractors and 3% for pickup trucks.

Equipment operating cost distribution for draglines and support equipment is

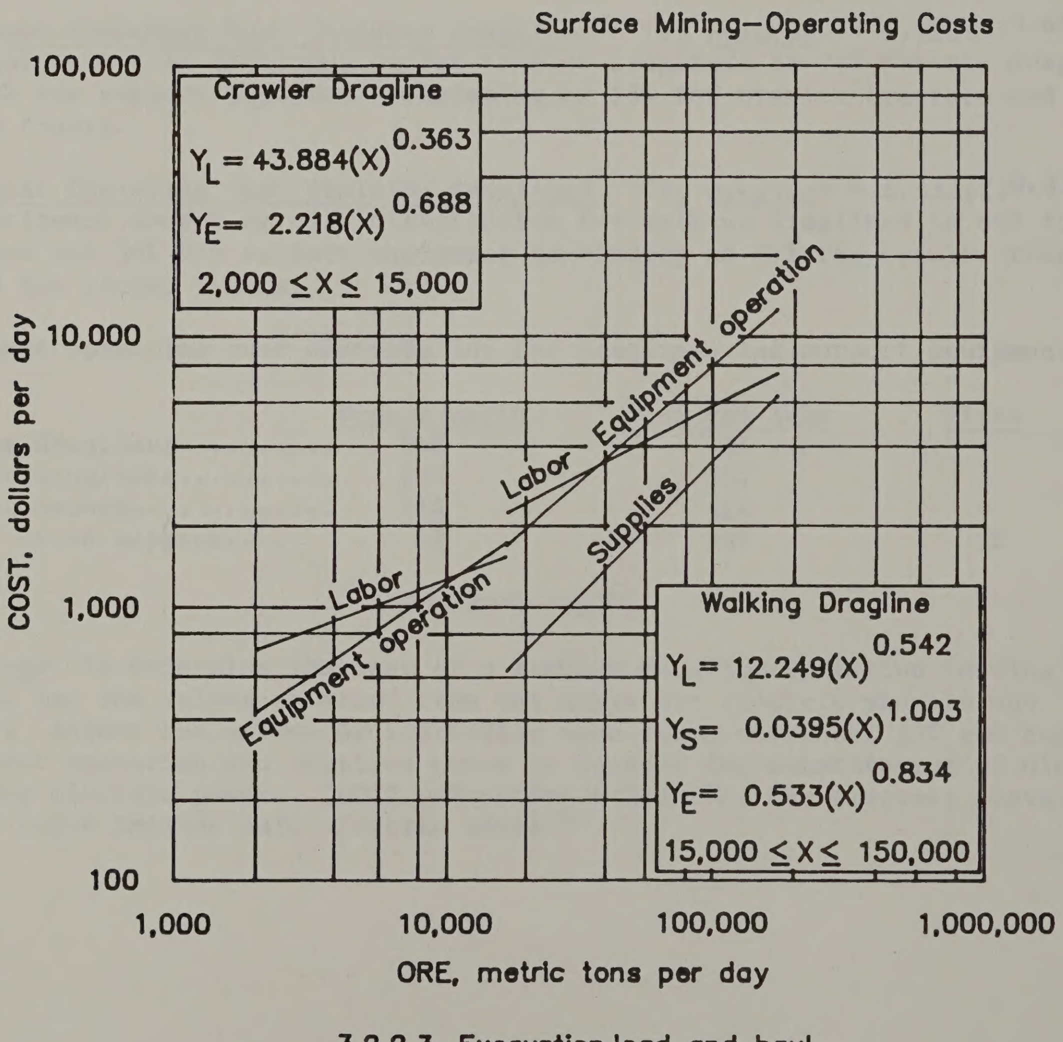
	Repair parts	Fuel and lube	Tires
Walking draglines..........	94%	6%	-
Crawler draglines..........	65%	35%	-
Crawler dozers.............	49%	51%	-
Rubber-tired support....	8%	90%	2%

ADJUSTMENT FACTOR

Truck Haulage To determine the cost of a crawler dragline operation loading to trucks, use the values obtained from the curve for electric shovels and trucks. Adjust the values by increasing each curve component 25% and combine equipment operation and supplies curve to account for substitution of diesel fuel for electric power. (NOTE.--Supplies values for the electric shovels and trucks curve include only electric power.)

LIMITATIONS OF DRAGLINE EXCAVATION CURVES

The cost curves for draglines are very general and are meant to represent a typical excavating operation. Factors that greatly affect dragline excavation costs include the swing angle of boom and hoisting height.



3.2.2.3. Excavation,load and haul
DRAGLINES

3.2. SURFACE MINING--OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.4. EXCAVATION, LOAD AND HAUL ORE
DREDGING

There are basically two kinds of dredging systems used in placer mining and in construction: mechanical, such as the bucket-line dredges, and hydraulic such as the suction dredges (bucket wheel and cutterhead types).

The curves for dredging in this section cover costs for single bucket-line dredges, which are used in the most common method of placer excavation and recovering of free gold, platinum, tin, sand, and gravel. Suction dredges are mostly used in construction, in fine-sand mining and (only to a very minor extent) in placer mining; consequently, they are not included in the curves.

Bucket-line dredge operations normally work continuously 9 to 12 months per year, depending on weather conditions. Cleanup and repairs are performed one or two shifts per week. The total daily cost is the sum of the three separate cost curves (labor, supplies and equipment operation) based on a production rate (X) in bank cubic meters of material dredged per day. The curves are valid for operations between 500 and 20,000 bank m^3, operating three shifts per day. The curves cover dredging depths ranging from 10 to 50 m below the pond water level. All the cost components exclude mineral processing.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 302.529(X)^{0.254}$
The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The direct labor costs consist of the following typical range of personnel:

	Small (500 to 4,000 m^3)	Large (4,000 to 20,000 m^3)	Av salary per hour (base rate)
Winch operator.............	47%	28%	$21.32
Oiler......................	39%	39%	17.69
Helper.....................	14%	33%	14.56

Labor costs average $18.18 per worker-hour for all levels of production (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.692(X)^{0.724}$
The supply cost consists of 100% electric power. Typically, dredges are supplied with purchased power.

(E) Equipment Operating Cost $(Y_E) = 7.454(X)^{0.595}$
Equipment operation costs consist of 95% parts and 5% lubricants.

ADJUSTMENT FACTORS

Depth Factor To adjust the costs for actual dredging depths and swell factors, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.65+[3.33(D)(X)^{-0.615}]$

Supply factor $(F_S) = 7.62(D)(S)^{-1.0}(X)^{-0.615}$

Equipment operation factor $(F_E) = 7.62(D)(S)^{-1.0}(X)^{-0.615}$
where D = actual depth, in meters,
X = volume to be dredged, in bank cubic meters per day,
and S = actual swell factor (the reciprocal of 1 plus the decimal equivalent of percent swell); the base swell factor is 0.80.

Mineral Processing Factor To include operating cost of a mineral process plant mounted on the dredge (i.e., jigging or other gravity separation method), multiply the costs obtained from the curves by the following factors:

Minimal mineral processing:

Labor factor $(F_{L\ MINIMAL}) = 1.51$
Supply factor $(F_{S\ MINIMAL}) = 1.34$
Equipment operation factor $(F_{E\ MINIMAL}) = 1.37$

Some mineral processing:

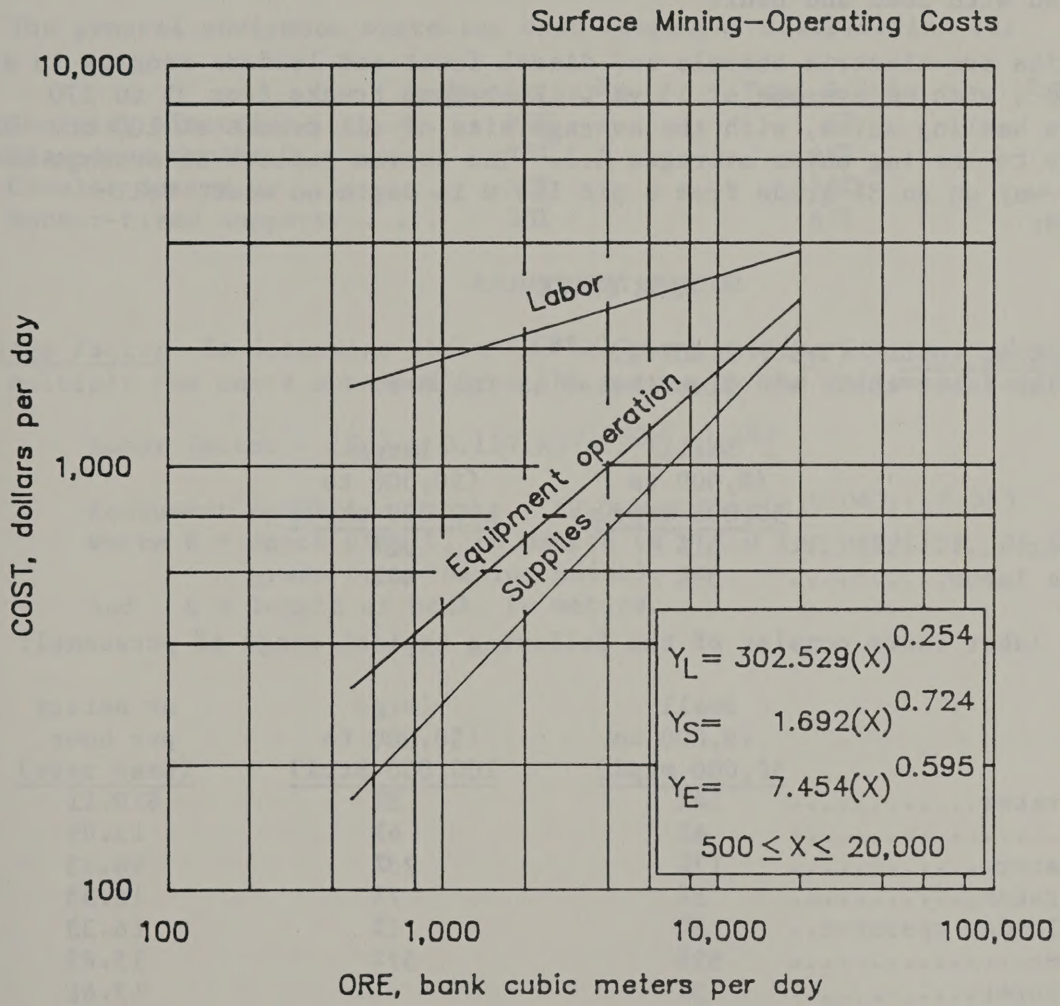
Labor factor $(F_{L\ SOME}) = 1.57$
Supply factor $(F_{S\ SOME}) = 1.36$
Equipment operation factor $(F_{E\ SOME}) = 1.41$

Complex mineral processing:

Labor factor $(F_{L\ COMPLEX}) = 1.63$
Supply factor $(F_{S\ COMPLEX}) = 1.38$
Equipment operation factor $(F_{E\ COMPLEX}) = 1.45$

Power For locations where electric power can not be purchased, estimate the supply cost using the curve for portable power generation (section 3.2.4.6.). If the actual number of kilowatt-hours of power consumption is available, estimate the supply cost by multiplying the kilowatt-hours by the actual cost per kilowatt-hour.

Multiple Dredges If the surface mine operation requires more than one dredge, estimate the operating costs separately for each dredge with the curves and the applicable factors given. The manual user should be aware that the combined labor cost might be slightly lower than the sum of the separate labor costs because of improved maintenance-labor distribution for the dredges.



3.2.2.4. Excavation, load and haul
DREDGING

3.2. SURFACE MINING - OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.5. EXCAVATION, LOAD AND HAUL ORE ELECTRIC SHOVEL AND TRUCKS

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore per day. The curves are valid for operations between 8,000 and 100,000 mtpd, operating three shifts per day. The curves include all daily operations and maintenance costs associated with load and haul.

The loading units are electric shovels and diesel front-end loaders ranging in size from 5 to 30 yd^3, with an average of 15 yd^3. Rear-dump trucks from 35 to 170 st are the main hauling units, with the average size of all trucks at 100 st. The ratio of trucks to loading units averages 6:1. The curves reflect an average haul of 2,000 m one-way on an 8% grade from a pit 120 m in depth on wide, well-maintained roads.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2.407(X)^{0.782}$
The operating labor costs are distributed as follows:

	Small (8,000 to 50,000 mtpd)	Large (50,000 to 100,000 mtpd)
Direct labor...............	61%	53%
Maintenance labor..........	39%	47%

The direct labor costs consist of the following typical range of personnel:

	Small (8,000 to 50,000 mtpd)	Large (50,000 to 100,000 mtpd)	Av salary per hour (base rate)
Shovel operator............	14%	8%	$18.11
Oiler......................	6%	4%	15.89
Dozer operator.............	17%	23%	16.33
Grader operator............	5%	7%	16.33
Front-end loader operator..	3%	1%	16.33
Truck driver...............	52%	57%	15.89
General laborer............	3%	-	13.66

Labor costs average $16.54 per worker-hour for all levels of production (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.0671(X)^{0.856}$
The supply cost consists of 100% electric power for electric shovels.

(E) Equipment Operating Cost $(Y_E) = 1.284(X)^{0.882}$

The equipment operating cost covers the daily operating cost for all excavation, loading, and hauling equipment and includes allowances for repair parts, tires, lubrication, and fuel consumption.

Equipment operating cost distribution for an electric shovel and truck operation is

Shovel, electric...........	7%
Rear-dump trucks...........	70%
Crawler dozers.............	12%
Rubber-tired support.......	11%

The general equipment operating cost component distribution is:

	Repair parts	Fuel & lube	Tires
Shovels, electric..........	96%	4%	-
Rear-dump trucks...........	25%	48%	27%
Crawler dozers.............	50%	50%	-
Rubber-tired support.......	35%	47%	18%

ADJUSTMENT FACTOR

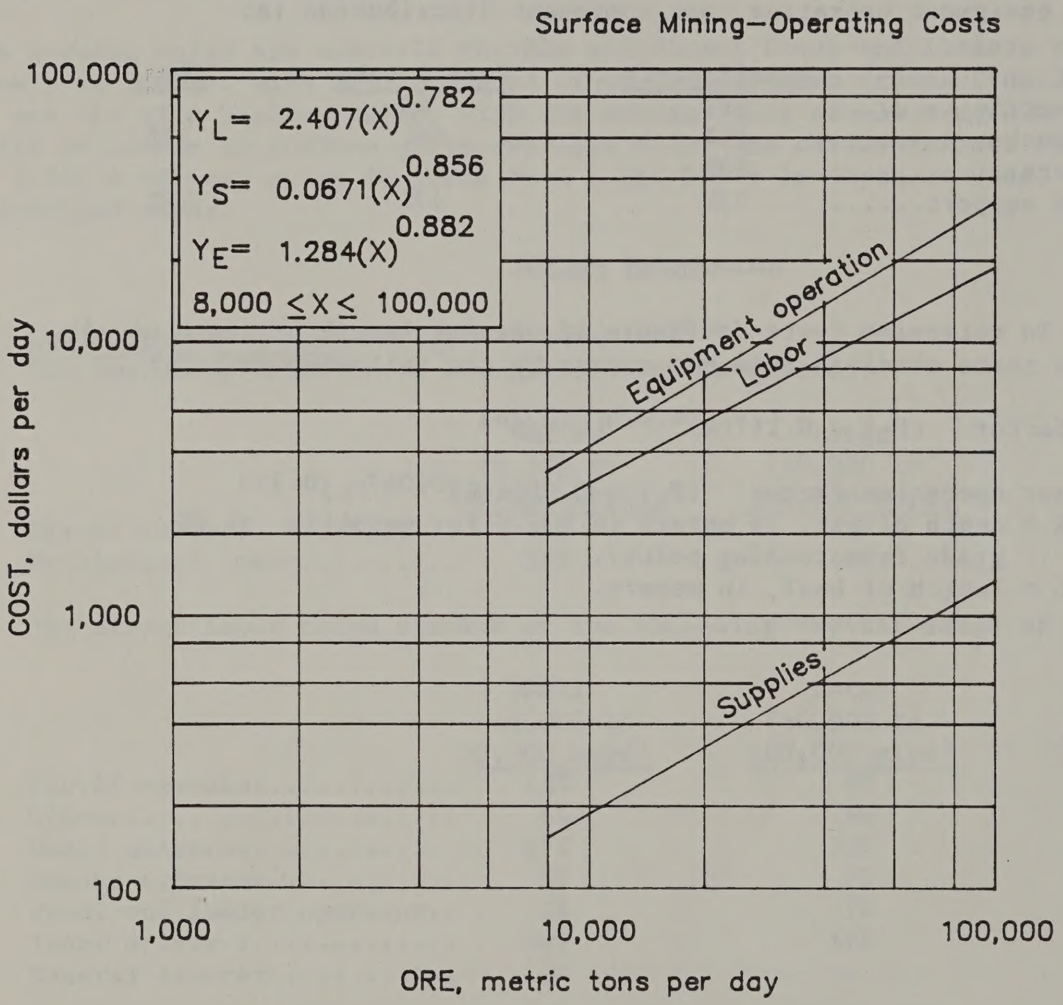
Haulage Factor To determine costs for hauls of varying length or depth of pit, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.117(R)^{0.030}(L)^{0.263}$

Equipment operation factor $(F_E) = 0.0546(R)^{0.047}(L)^{0.353}$

where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from loading point),

and L = length of haul, in meters.



3.2.2.5. Excavation, load and haul
ELECTRIC SHOVEL AND TRUCKS

3.2. SURFACE MINING--OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.6. EXCAVATION, LOAD AND HAUL ORE
FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

The curve shows the cost per day for loading and hauling both common and shot rock. For common earth excavation, 1 bank m^3 equals 2.08 mt; for shot rock, 1 bank m^3 equals 2.61 mt.

The curve is based on mines using front-end loaders or diesel shovels for loading and trucks for haulage. The loaders and shovels range in size from 1 to 6 yd^3 and the trucks range from 10 to 35 st. The curves reflect an average haul of 750 m one way on an 8% grade from a pit 60 m in depth.

The total daily cost is the sum of the two separate cost curves (labor and equipment operation) based on a production rate (X), in metric tons of ore per day. The curves are valid for operations between 100 and 10,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with excavation, loading, and haulage.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 37.003(X)^{0.529}$
The operating labor costs are distributed as follows:

Direct labor...............	70%
Maintenance labor..........	30%

The direct labor costs consist of the following typical range of personnel:

	Small (100 to 3,000 mtpd)	Large (3,000 to 10,000 mtpd)	Av salary per hour (base rate)
Loader/shovel crew.........	30%	21%	$16.24
Truck haulage crew.........	46%	37%	15.89
Dozer operator.............	24%	17%	16.33
Rubber-tired support crew......................	-	25%	16.11

A typical small front-end loader-diesel shovel and truck operation is based on a composite crew having an average rate of $16.20 per worker-hour (including burden and average shift differential). Large load and haul operations are based on a composite crew having an average rate of $16.42 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 24.620(X)^{0.576}$
The equipment operating cost distribution for front-end loader-diesel shovel and truck operation is

Loader/shovel..............	18%
Rear-dump truck............	43%
Crawler dozer..............	23%
Rubber-tired support.......	16%

The general equipment cost component distribution is as follows:

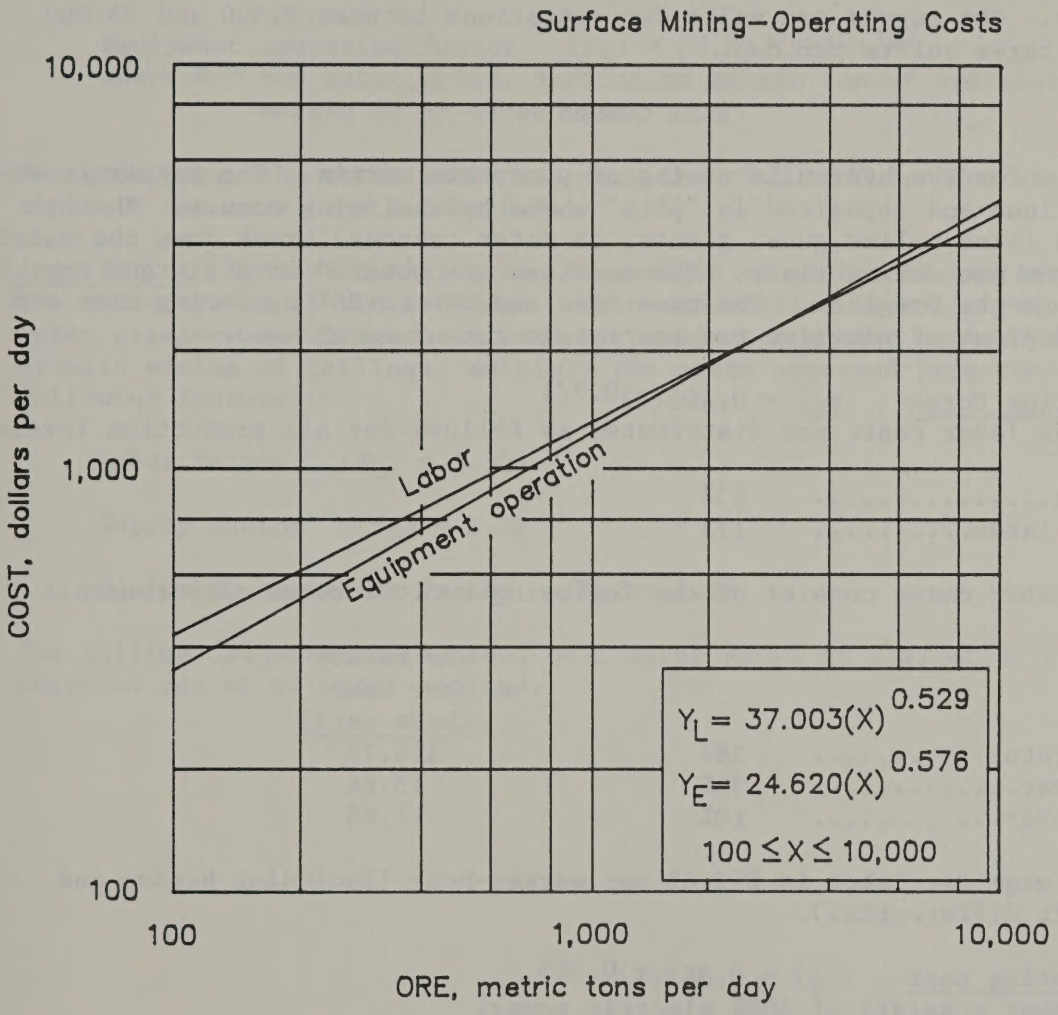
	Repair parts	Fuel and lube	Tires
Shovel, diesel.............	70%	30%	-
Front-end loader...........	33%	44%	23%
Rear-dump truck............	28%	52%	20%
Crawler dozer..............	51%	49%	-
Rubber-tired support.......	28%	63%	9%

ADJUSTMENT FACTOR

Haulage Factor To determine costs for hauls of varying haul length or depth of pit, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.155(R)^{0.030}(L)^{0.263}$

Equipment operation factor $(F_E) = 0.080(R)^{0.047}(L)^{0.353}$
where R = depth of pit, in meters (R = 1.0 for negative or 0% grade from the loading point),
and L = length of haul, in meters.



3.2.2.6. Excavation, load and haul
FRONT-END LOADER OR DIESEL SHOVEL AND TRUCKS

3.2. SURFACE MINING--OPERATING COSTS

3.2.2. MINING OF ORE

3.2.2.7. EXCAVATION, LOAD AND HAUL ORE HYDRAULIC MINING

The operating costs for hydraulic mining are given on a metric ton per day of ore slurried. The costs include the operation of the monitors and high-pressure water pumps. Not included in the estimates is the cost for pumping the slurry. The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of material slurried per day. The curves are valid for operations between 9,500 and 58,000 mtpd, operating three shifts per day.

BASE CURVES

The base curve is for the hydraulic mining of phosphate matrix. The matrix is excavated by draglines and deposited in "pits" where hydraulicing occurs. The hydraulic monitors (also called guns, giants, or water cannons) break down the matrix for pumping to the processing plant. The monitors are mounted on a pit gun car that advances with the dragline. The base case assumes an 85% operating time and a water ratio of 0.67 mt of slurried ore per metric ton of water used.

(L) Labor Operating Curve $(Y_L) = 0.406(X)^{0.771}$
The operating labor costs are distributed as follows for all production levels:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Moniter operator...........	58%	$16.78
Moniter helper.............	32%	13.66
Moniter laborer............	10%	11.68

The average wage for labor is $15.65 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.883(X)^{0.685}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.019(X)^{0.748}$
The equipment operating cost consists of monitor repair parts and materials. The repair costs are divided 30% for water pumps and 70% for the monitor systems (hydraulic pumps, controls, and monitors).

ADJUSTMENT FACTORS

Water Ratio Factor Each deposit to be hydraulically mined will require different quantities of water, and therefore, different sizes or numbers of monitors. The more competent (tougher) the deposit, the more water that will be required. The measure of difficulty in slurrying the deposit is the mass ratio of ore excavated to water used. To adjust the base curves for different water requirements, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [0.67/(R)]^{0.050}$

Supply factor $(F_S) = [0.67/(R)]^{1.285}$

Equipment operation factor $(F_E) = [0.67/(R)]^{0.327}$
where R = new water ratio, defined as metric ton of ore slurried per metric of of water used.

For phosphate, the water ratio can vary from 0.7 to 0.3. For other applications it can vary from 1.5 to 0.2.

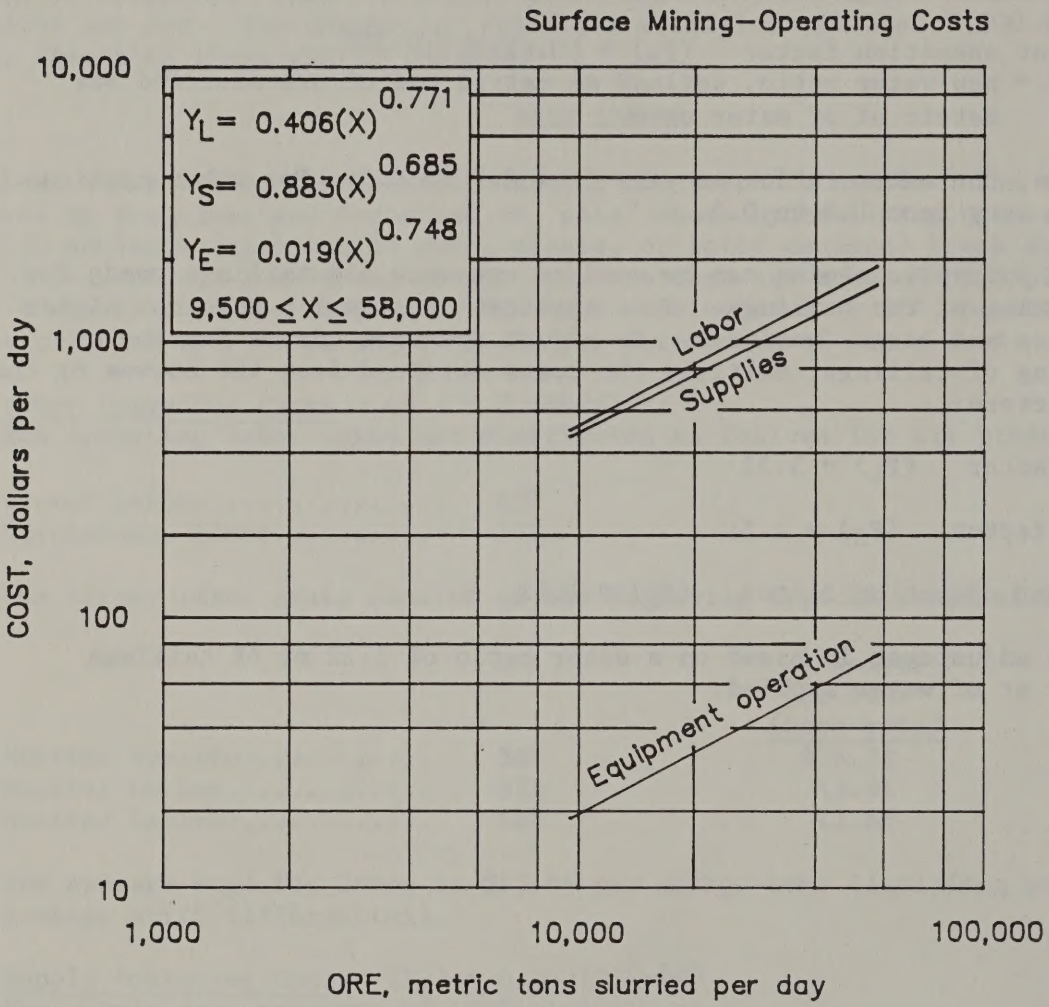
Tailings Factor Hydraulic mining can be used to excavate old tailings ponds for the reprocessing of the tailings. This application normally requires higher water pressure and larger monitors. To adjust the base curves for the hydraulic mining of tailings, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 3.32$

Supply factor $(F_S) = 1.51$

Equipment operation factor $(F_E) = 1.12$

The tailings adjustment is based on a water ratio of 1.22 mt of tailings slurried per mt of water applied.



3.2.2.7. Excavation load and haul
HYDRAULIC MINING

3.2. SURFACE MINING--OPERATING COSTS

3.2.3. TRANSPORTATION

3.2.3.1. AERIAL TRAMWAY

The operating cost curves for aerial tramways cover the cost for tramming ore or waste material. The base curves are based on an aerial tramway of 3.0 km in length with a slope of 15°. The bulk density of trammed material is 1,442.5 kg/m^3 (92.0 lb/ft^3). The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of material transported per day. The curves are valid for operations between 2,040 and 13,800 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 439.940(X)^{0.121}$
The operating labor costs are distributed as follows for all production levels:

Direct labor...............	65%
Maintenance labor..........	35%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Tram operator..............	50%	$16.78
Tram helper................	41%	13.66
Tram laborer...............	9%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.815(X)^{0.451}$
The supply curve consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 68.358(X)^{0.381}$
The equipment operating cost consists of 99.4% for repair parts and materials and 0.6% for lubrication. The curve includes allowance for repairs on motors, feeder conveyor, hoppers, scales, bin, tram cars, ropes, and maintenance of automatic loading and unloading systems and all other pieces of equipment directly associated with the aerial tramways.

ADJUSTMENT FACTORS

Aerial Tramway Length Factor The base curve is calculated for an aerial tramway 3 km in slope length. To adjust the base curve for a different aerial tramway slope length, multiply the costs obtained from the base curves by the following factors:

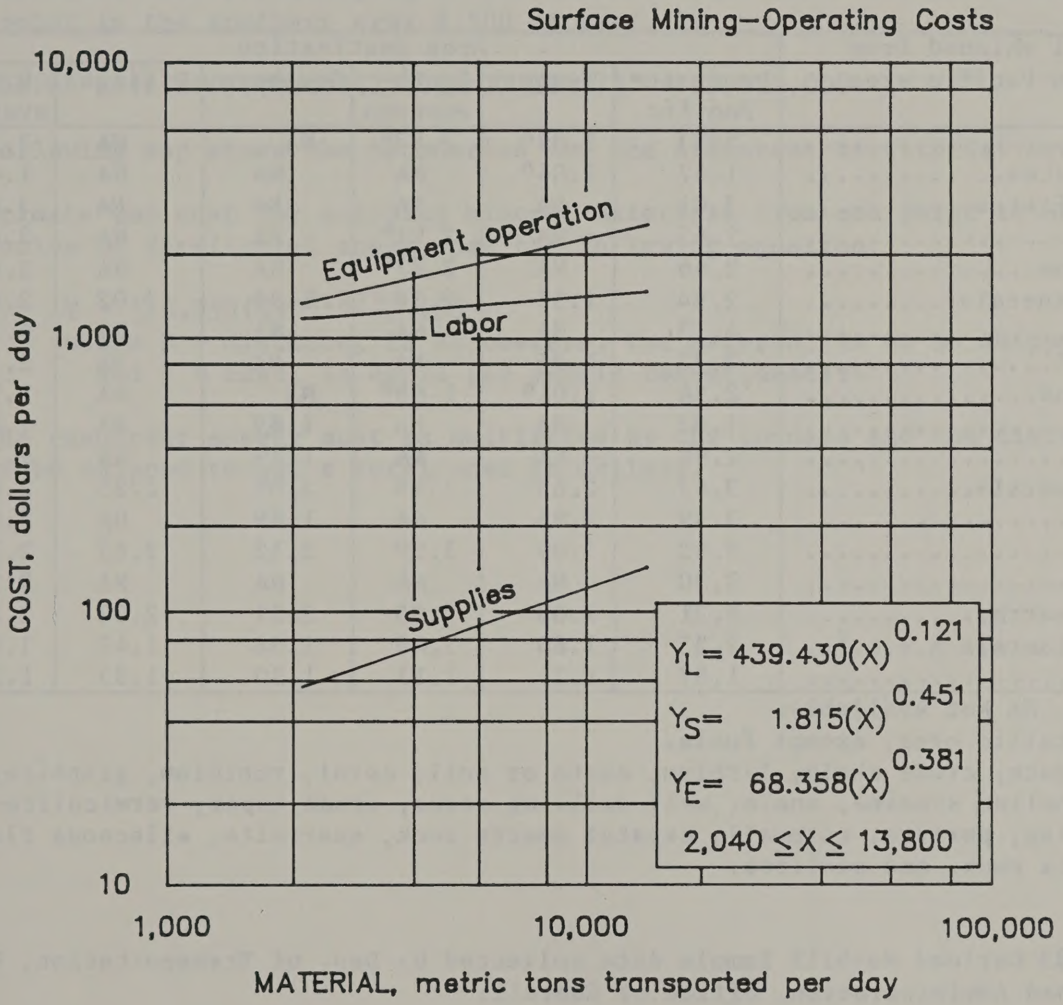
Labor factor $(F_L) = 0.113(L)+0.660$

Supply factor $(F_S) = 0.157(L)+0.528$

Equipment operation factor $(F_E) = 0.226(L)+0.321$
where L = slope length, in kilometers.

Bulk Density Factor The curve was based on material bulk density of 1,442.5 kg/m^3 (92.0 lb/ft^3) of material trammed (see table A-2 for average bulk densities of various materials). To adjust the base curve for a different material bulk density, multiply the costs obtained from the equipment operating curve by the following factor:

Equipment operation factor $(F_E) = 0.00003(D)+0.957$
where D = density, in kilograms per cubic meter.



3.2.3.1. Aerial tramway

3.2. SURFACE MINING--OPERATING COSTS

3.2.3. TRANSPORTATION

3.2.3.4. LONG DISTANCE RAIL HAULAGE

The following tablulation gives the average cost, in cents per metric ton-kilometer, for shipping mineral materials from the Mountain-Pacific territorial area (including Denver, CO) to any of the five territorial areas within the continental United States. This information is valid as of January 1984.

AVERAGE SHIPPING COSTS FOR MINERAL MATERIALS, cents per metric ton-kilometer

Material shipped from Mountain-Pacific area	Area destination					
	Mountain-Pacific	Western	South-western	Southern	Official	U.S. average
Metallic ores..................	2.53	1.04[e]	2.87[e]	NA	NA	2.33
Iron concentrates.............	1.47	1.04[e]	NA	NA	NA	1.47
Copper precipitates...........	3.01	NA	NA	NA	NA	3.01
Bauxite ore...................	2.65	NA	2.91[e]	NA	NA	2.67
Alumina calcine...............	2.66	NA	2.87[e]	NA	NA	2.66
Nonmetallic minerals[1].........	2.94	1.55	2.18	1.96	2.02	2.68
Crushed stone.................	4.13	NA	NA	NA	NA	4.11
Sand or gravel................	2.73	4.75	NA	NA	NA	2.74
Industrial sand...............	2.54	1.01[e]	1.68[e]	NA	NA	2.54
Refractories..................	1.83	NA	NA	1.89	NA	1.85
Clay minerals.................	2.94	NA	NA	1.89	NA	2.37
Fertilizer minerals...........	3.47	2.65	1.49	2.05	2.25	2.09
Borate, crude.................	3.39	2.85	NA	1.89	NA	2.67
Sulfur........................	3.82	3.09	1.99	2.12	2.62	2.34
Gypsum crude..................	3.30	NA	NA	NA	NA	3.30
Diatomaceous earth............	4.31	2.03	2.05	2.31	2.32	2.22
Nonmetallic minerals n.e.c.[2]..	2.35	1.84	1.49	1.58	1.47	1.63
Coal..........................	1.87	1.25	1.13	1.30	1.33	1.26

[e] Estimated. NA Not available.

[1] Most nonmetallic ores, except fuels.

[2] Includes agate, crude chalk, lithium, earth or soil, coral, rubidium, graphite, sericite, nepheline syenite, shale, well drilling cores, crude topaz, vermiculite-unexpanded, slag, perlite, cornwall, crystal quartz rock, quartzite, silaceous fluxing ore, silica rock, and zeolites.

Source: 1983 Carload Waybill Sample data collected by Dep. of Transportation, Federal Federal Railroad Administration, Office of Conrail.

Costs for shipping certain mineral materials from the Mountain-Pacific area to other areas may be not available for two reasons; first, shipments of these materials has dropped dramatically during the last 10 yr, making evaluation of costs impossible. Second, certain mineral materials are typically not shipped between two areas. For example, copper precipitates traditionally are never shipped out of the Mountain-Pacific area.

To determine the total cost of transporting a specific mineral material, first select the appropriate cost from the tabulation, then multiply that value by the distance in kilometers the material is to be shipped, and also by the metric tonnage to be shipped. Finally, divide the answer by 100 to get a value in dollars.

Example: The cost for shipping 100,000 mt of fertilizer minerals from Denver, CO, to a point in the southern area 2,500 km away, is

$$[(2.05¢/\text{mt}\cdot\text{km})\times(100{,}000\text{mt})\times(2{,}500\text{km})/(100¢/\$) = \$5{,}125{,}000.$$

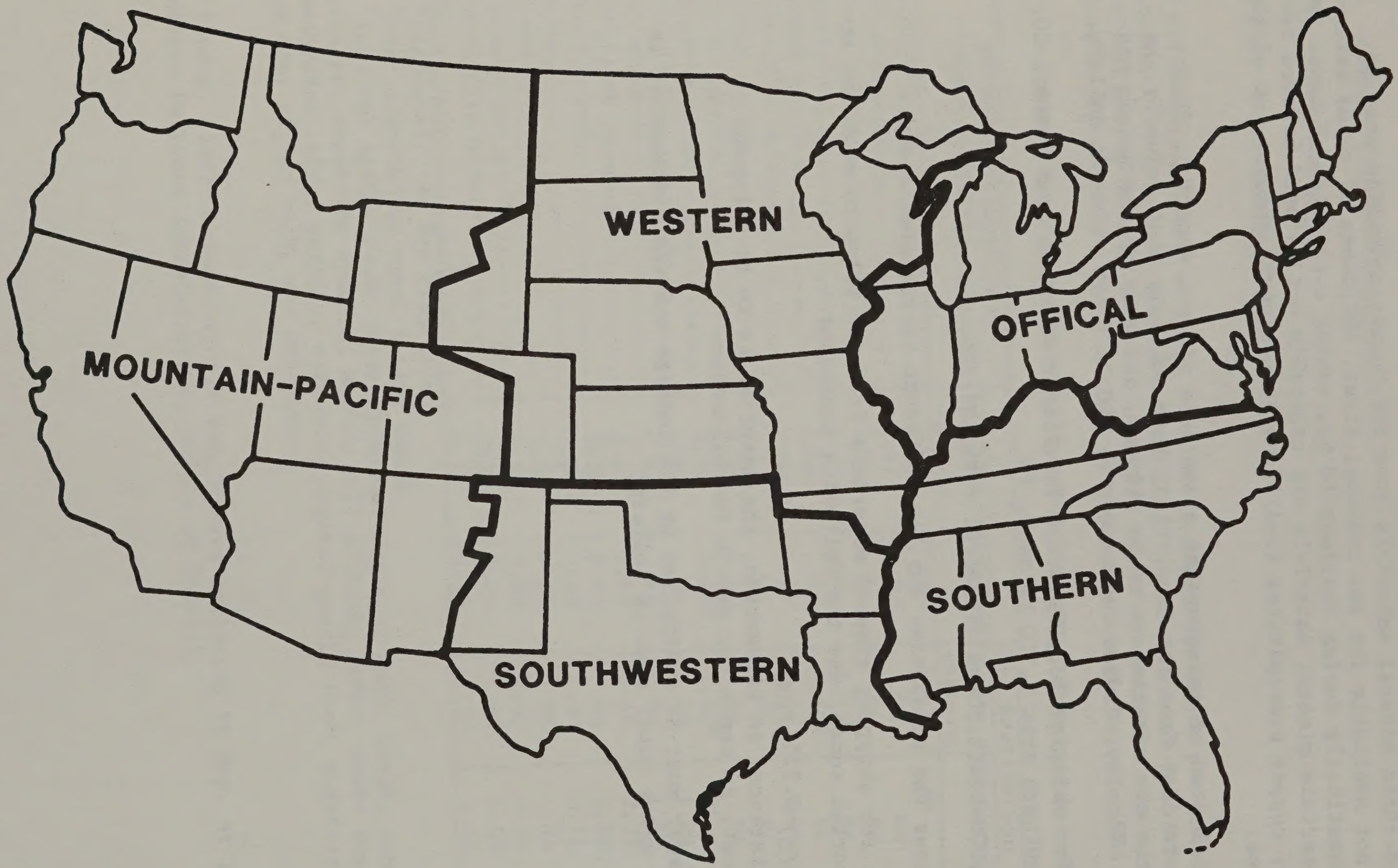
The following map shows the boundaries for the different territorial areas.

To estimate the cost for shipping mineral materials from one point to another, irrespective of territorial zones, use the following equation:

$$Y = [15.359(D)^{-0.275}]/100$$

where D = distance, in kilometers, the material is to be shipped,
and Y = cost, in cents per metric ton-kilometer.

The resultant answer must be multiplied by the tonnage and the distance it is to be shipped to get a total cost in dollars.


WESTERN
OFFICAL
MOUNTAIN-PACIFIC
SOUTHERN
SOUTHWESTERN

3.2. SURFACE MINING--OPERATING COSTS

3.2.3. TRANSPORTATION

3.2.3.5. LONG DISTANCE SURFACE CONVEYOR

These curves cover the cost of transporting material from the mine via a single-flight conveyor belt reinforced with high-strength steel and cover a capacity range of 15,000 to 150,000 mtpd. The material is conveyed up a 10° slope for a distance of 1 km. The conveyor availability is 94%. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher costs are not included in this cost but are covered in separate sections.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons material transported per day. The curves are valid for operations between 15,000 and 150,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the conveyor operation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 7.429(X)^{0.464}$
The operating labor costs are distributed as follows:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)
Direct labor...........	71%	47%
Maintenance labor.......	29%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)	Av salary per hour (base rate)
Operator................	64%	54%	$16.25
Assistant operator......	36%	46%	13.97

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.068(X)^{0.933}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.226(X)^{0.358}$
The equipment operating cost consists of 95% for repair parts and 5% for lubrication for the idlers and mechanical parts.

ADJUSTMENT FACTOR

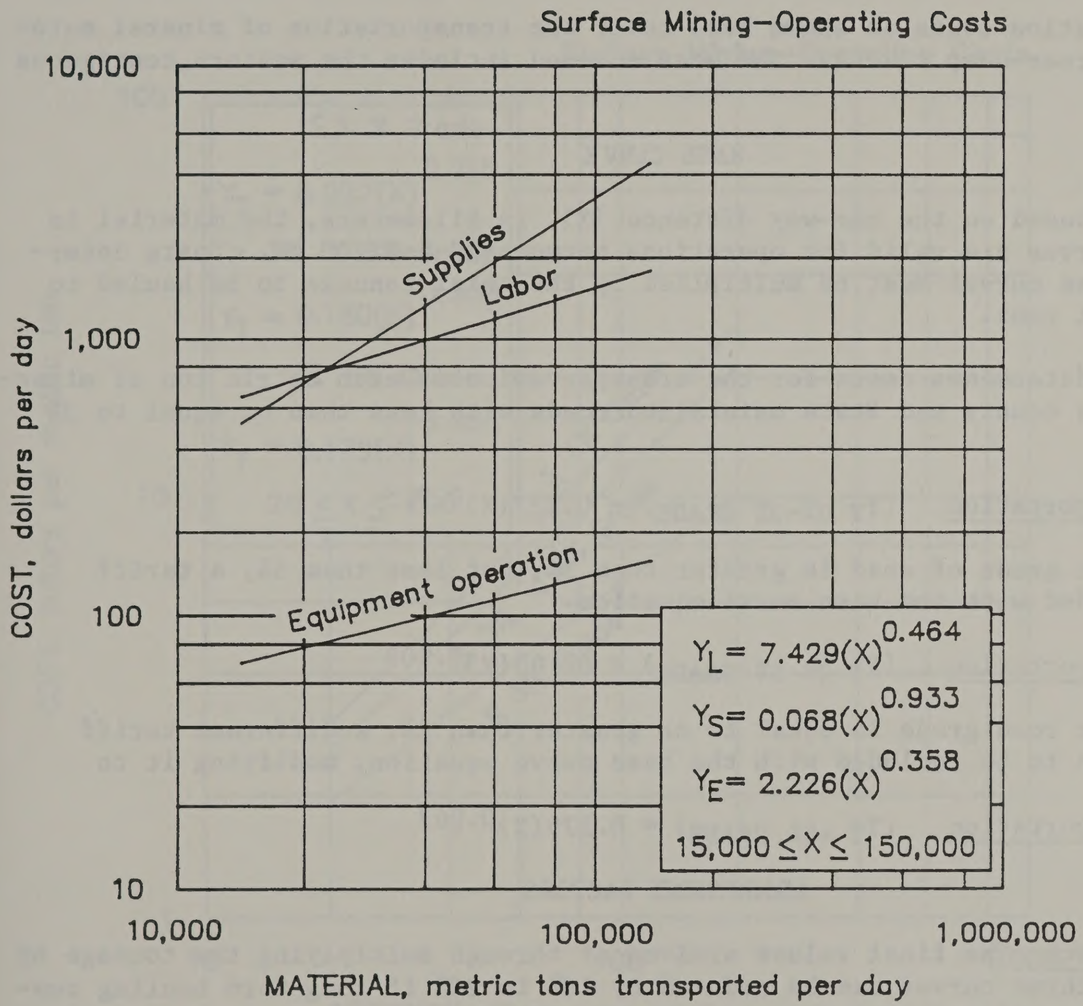
Length and Slope Factor To determine costs for varying conveyor lengths and slopes, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.815+0.190(L)$

Supply factor $(F_S) = [0.208+0.0794(S)][(L/1)]$

Equipment operation factor $(F_E) = L/1$
where L = length of conveyor, in kilometers,
and S = slope of conveyor, in degrees (S is between 0° and 15°).

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).



3.2.3.5. Long distance surface conveyor

3.2.3.6. LONG-DISTANCE TRUCK HAULAGE

The trucking industry has undergone intensive change since its recent deregulation. Truck transportation of mineral materials has shifted predominantly away from the class rate system to the bulk commodity method. This has corresponded with a decrease in the number of carriers and an increase in competition. Each carrier now determines its own rate and tariff schedules.

Truck transportation costs as shown here cover the transportation of mineral materials by 23-mt rear-dump trucks. The area covered includes the western contiguous United States.

BASE CURVE

The curves are based on the one-way distance (X), in kilometers, the material is hauled. The curves are valid for operations between 20 and 200 km. Costs determined using these curves must be multiplied by the total tonnage to be hauled to obtain the final cost.

The base curve determines costs for the transportation of each metric ton of mineral materials via county and State maintained roads with less than or equal to 3% grades.

(T) Truck transportation $(Y_{T\ 0\%-3\%\ GRADE}) = 0.227(X)^{0.715}$

When the average grade of road is greater than 3%, but less than 6%, a tariff factor is included with the base curve equation.

(T) Truck transportation $(Y_{T\ 3\%-6\%\ GRADE}) = 0.180(X)^{0.909}$

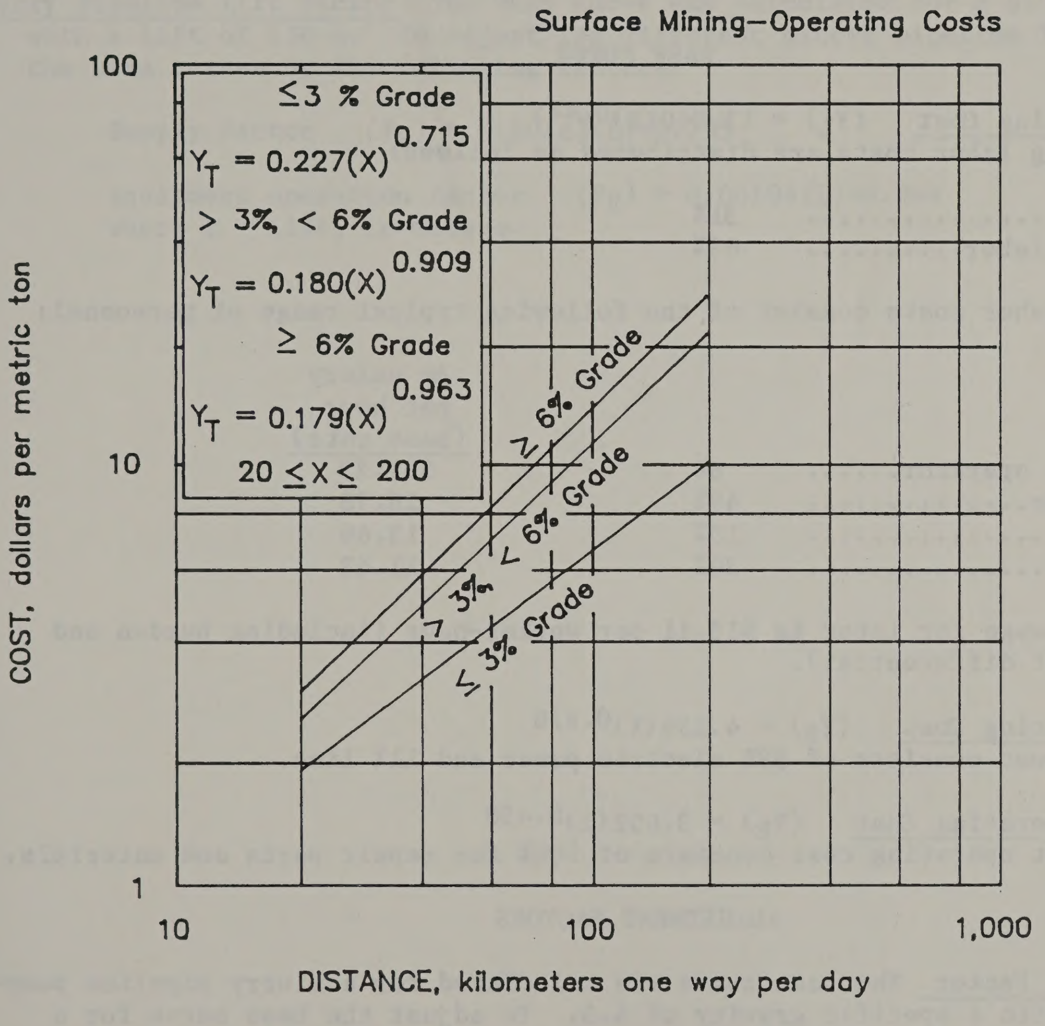
When the average road grade is equal to or greater than 6%, a different tariff factor will have to be included with the base curve equation, modifying it to

(T) Truck transportation $(Y_{T\ +6\%\ GRADE}) = 0.179(X)^{0.963}$

ADJUSTMENT FACTORS

Long-Term Contract The final values arrived at through multiplying the tonnage by any of the three curves can be reduced by 10% to 20% if long-term hauling contracts are to be used.

Tonnage If trucks with carrying capacities greater or less than 23 mt are used, the cost per metric ton should be modified accordingly.



3.2.3.6. Long distance truck haulage

3.2. SURFACE MINING--OPERATING COSTS

3.2.3. TRANSPORTATION

3.2.3.8. SLURRY PIPELINE

The operating cost curves for slurry pipeline cover the cost of transporting a slurry. The base curves are based on a slurry pipeline of 10 km in length with a lift of 150 m pumping solids at specific gravity of 4.3. The total cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) at an adjusted feed rate (X), in metric tons material transported per day. The curves are valid for operations between 900 and 32,000 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 13.940(X)^{0.445}$
The operating labor costs are distributed as follows:

Direct labor...............	31%
Maintenance labor..........	69%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control room operator......	6%	$17.23
Mill operator..............	49%	16.78
Mill helper................	15%	13.66
Mill laborer...............	30%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.259(X)^{0.676}$
The supply cost consists of 89% electric power and 11% lime.

(E) Equipment Operating Cost $(Y_E) = 3.652(X)^{0.458}$
The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Specific Gravity Factor The base curve was calculated for a slurry pipeline pumping solids with a specific gravity of 4.3. To adjust the base curve for a different specific gravity, multiply the base curves by the following factors:

Supply factor $(F_S) = 0.0681(S)+0.707$

Equipment operation factor $(F_E) = 0.074(S)+0.683$
where S = specific gravity of the solids.

See the table A-3 in the appendix for average specific gravities.

Slurry Pipeline Length The base curve was calculated for a slurry pipeline of 10 km in length. To adjust for different slurry pipeline lengths, multiply the base curves by the following factors:

Labor factor (F_L) = 0.0026(P)+0.974

Supply factor (F_S) = 0.0172(P)+0.828

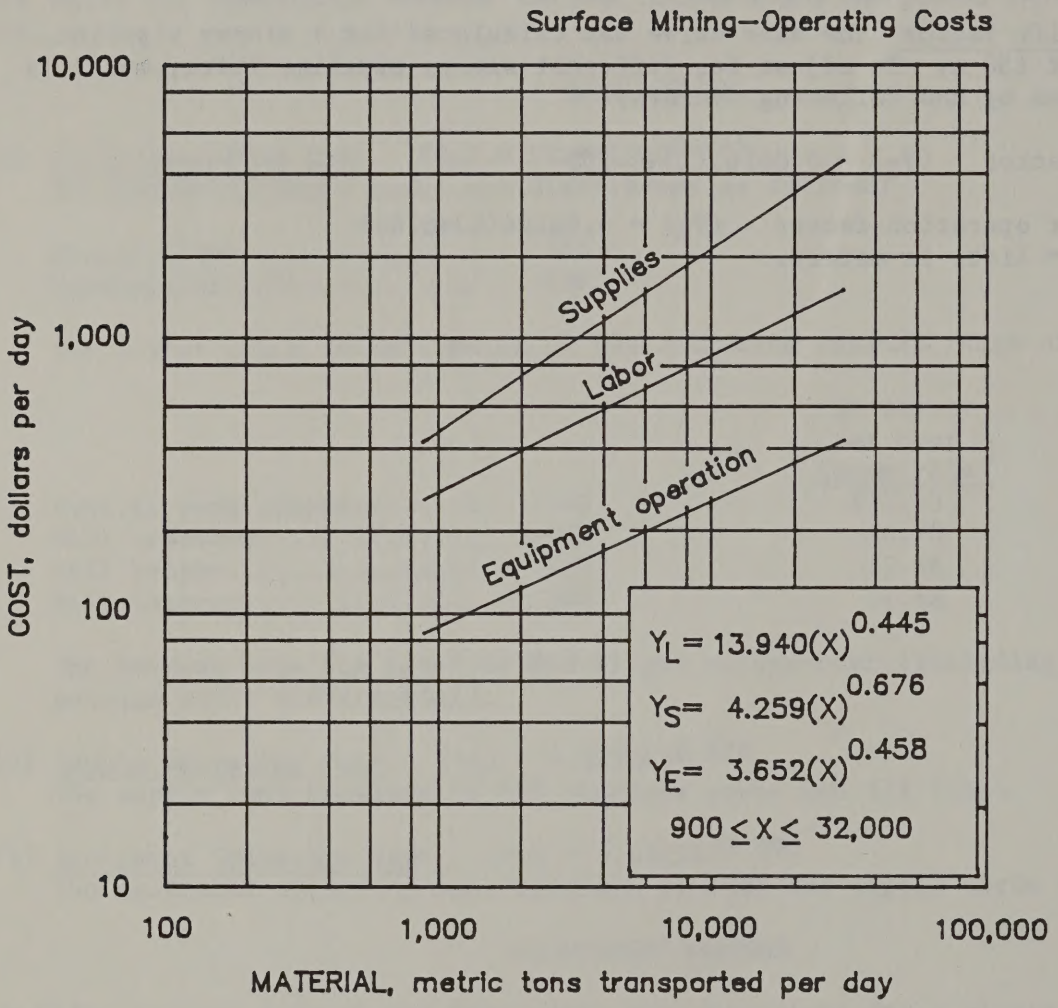
Equipment operation factor (F_E) = 0.011(P)+0.890
where P = length of pipeline, in kilometers.

See the table A-3 in the appendix for average pipeline lengths.

Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust for different slurry pipeline lifts, multiply the base curves by the following factors:

Supply factor (F_S) = 0.00163(L)+0.755

Equipment operation factor (F_E) = 0.00104(L)+0.844
where L = lift, in meters.



3.2.3.8. Slurry pipeline

3.2. SURFACE MINING--OPERATING COST

3.2.4. MINE PLANT GENERAL OPERATIONS

3.2.4.4. GENERAL ITEMS
COMMUNICATIONS, SANITATION, HOUSEKEEPING, FIRE PROTECTION, AND ELECTRICAL

This set of curves covers the cost for the general operations customarily required in surface mining operations. Examples of services provided are plumbing, miscellaneous repairs, rough and finish carpentry, incidental jobs, tire protection, electrical maintenance, and general housekeeping.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a feed rate (X), in metric tons ore and waste per day. The curves are valid for operations between 100 to 360,000 mtpd, operating three shifts per day. The curves include daily operating and maintenance costs associated with utility trucks, mobile cranes, fire trucks, various cleaning materials, and electrical and plumbing supplies.

BASE CURVE

(L) Labor Operating Cost $(Y_{L\ SMALL}) = 0.430(X)^{1.000}$
$(Y_{L\ LARGE}) = 11.829(X)^{0.520}$

The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

The labor costs consist of the following typical range of personnel:

	Small (100 to 1,000 mtpd)	Large (1,000 to 360,000 mtpd)	Av salary per hour (base rate)
Crane operator.............	18%	7%	$17.23
Truck driver...............	17%	6%	15.89
Carpenter, 1st class.......	-	7%	17.23
Carpenter, rough...........	17%	6%	16.33
General laborer............	30%	25%	13.86
Plumber, licensed..........	-	5%	18.11
Plumber, unlicensed........	-	4%	17.66
Welder, 1st class..........	18%	18%	16.78
Janitor....................	-	13%	14.56
Electrician................	-	9%	16.78

The average labor cost is $15.86 per worker-hour (including burden and average shift differential).

The size of the work force required for this work will vary from a small crew of 1 or 2 workers working a fractional day to possibly three shifts of from 50 to 60 workers per day.

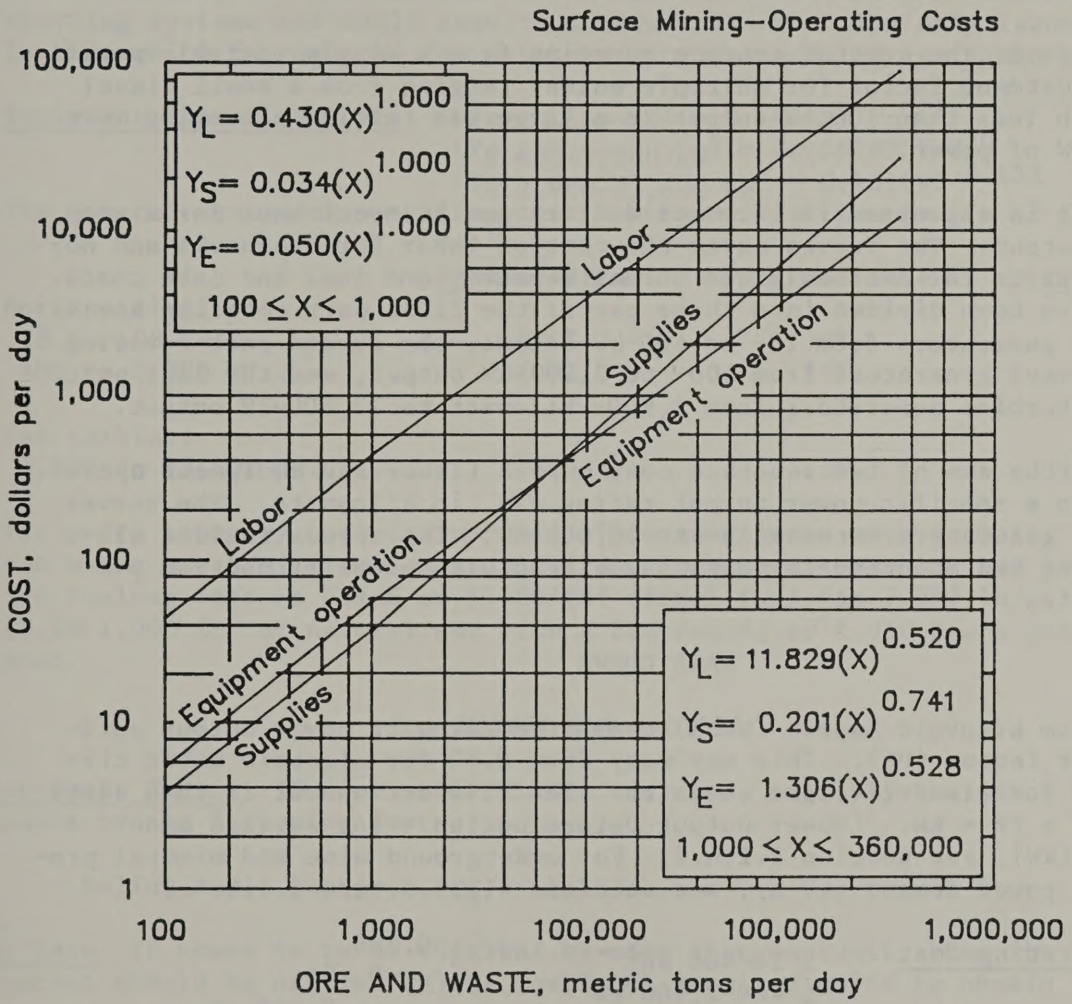
(S) Supply Operating Cost $(Y_{S\ SMALL}) = 0.034(X)^{1.000}$
$(Y_{S\ LARGE}) = 0.201(X)^{0.741}$

The supply cost consists of 100% miscellaneous materials, such as lumber, paper towels, nails, cleansers, etc.

(E) Equipment Operating Cost $(Y_{E\ SMALL}) = 0.050(X)^{1.000}$
$(Y_{E\ LARGE}) = 1.306(X)^{0.528}$

The general equipment cost component distribution is as follows:

	Small (100 to 1,000 mtpd)	Large (1,000 to 360,000 mtpd)
Repair parts...............	30%	37%
Fuel and lube..............	65%	57%
Tires......................	5%	6%



3.2.4.4. General items
COMMUNICATIONS, SANITATIONS, HOUSEKEEPING,
FIRE PROTECTION, AND ELECTRICAL

3.2. SURFACE MINING--OPERATING COST

3.2.4. MINE PLANT GENERAL OPERATIONS

3.2.4.6. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 2.2.4.2. when electric power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. The total cost per kilowatt hour replaces the commercial Denver, CO, power rate used in other sections of this manual.

These curves cover the cost of power production from a single portable power unit (see adjustment factor for multiple units) ranging from a small diesel generator with less than 100 kW output to a large gas turbine producing more than 20,000 kW of power.

The total cost is expressed in terms of dollars per kilowatt hour for a specific power output. The curves cover the cost of labor for overhauls and normal repairs, parts for overhauls and normal repairs, and fuel and lube costs. The curves have been divided into three parts: the first part covering horizontal diesel generators from 18- to 400-kW output, the second part covering horizontal diesel generators from 400- to 2,900-kW output, and the last part covering gas turbine generators from 2,900- kilowatt to 23,600-kW output.

Total cost is the sum of two separate cost curves (labor and equipment operation) based on a specific power output rating (X), in kilowatts. The curves are valid for generators between 18- to 23,600-kW. The curves include all daily operating and maintenance costs associated with power production per generator unit.

BASE CURVE

To convert from kilovolt ampere (kV•A) demand to kilowatt power output estimate the power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt output is then determined by kV•A x PF = kW. (Power Output Determination - for surface mine power output (kW), see section 2.2.4.2. For underground mine and mineral processing plant power demand (kV•A), see sections 4.2.5.3. and 6.1.8.4.)

(L) Labor Operating Cost $(Y_L \text{ 18-400 kW}) = 0.169(X)^{-0.466}$
$(Y_L \text{ 400-2,900 kW}) = 0.409(X)^{-0.480}$
$(Y_L \text{ 2,900-23,600 kW}) = 0.008(X)^{-0.445}$

The operating labor costs are distributed as follows:

Direct labor..............	0%
Maintenance labor.........	100%

The labor costs consist of the following typical range of personnel:

		Ag salary per hour (base rate)
Mechanics.................	100%	$18.11

The average wage for labor is $18.11 per worker-hour (including burden and average shift differential).

The labor curves do not contain any operating labor costs since all units operate unattended in an automatic mode (some smaller units may not have automatic starting systems and would require a manual start). The only labor necessary is that which is required for maintenance and scheduled overhauls by mechanics.

(E) Equipment Operation Costs $(Y_E \text{ 18-400 kW}) = 0.145(X)^{-0.075}$
$(Y_E \text{ 400-2,900 kW}) = 0.158(X)^{-0.070}$
$(Y_E \text{ 2,900-23,600 kW}) = 0.131(X)^{-0.122}$

The general equipment operating cost component distribution is as follows:

	Repair parts	Fuel and lube	Tires
Horizontal diesel:			
18 to 400 kW..............	18.0%	73%	9%
400 to 2,900 kW...........	12.0%	79%	9%
Gas turbine:			
2,900 to 23,600 kW........	11%	75%	14%

The parts category includes normal maintenance parts such as belts and pumps, and major overhaul items such as valves, injectors, brushes, and commutators. The fueling cost is based on $1.00/gal diesel fuel (at 7.093 lb/gal) or $3.20/1,000 ft^3 of natural gas with a Btu rating of 1,050 Btu's per cubic foot.

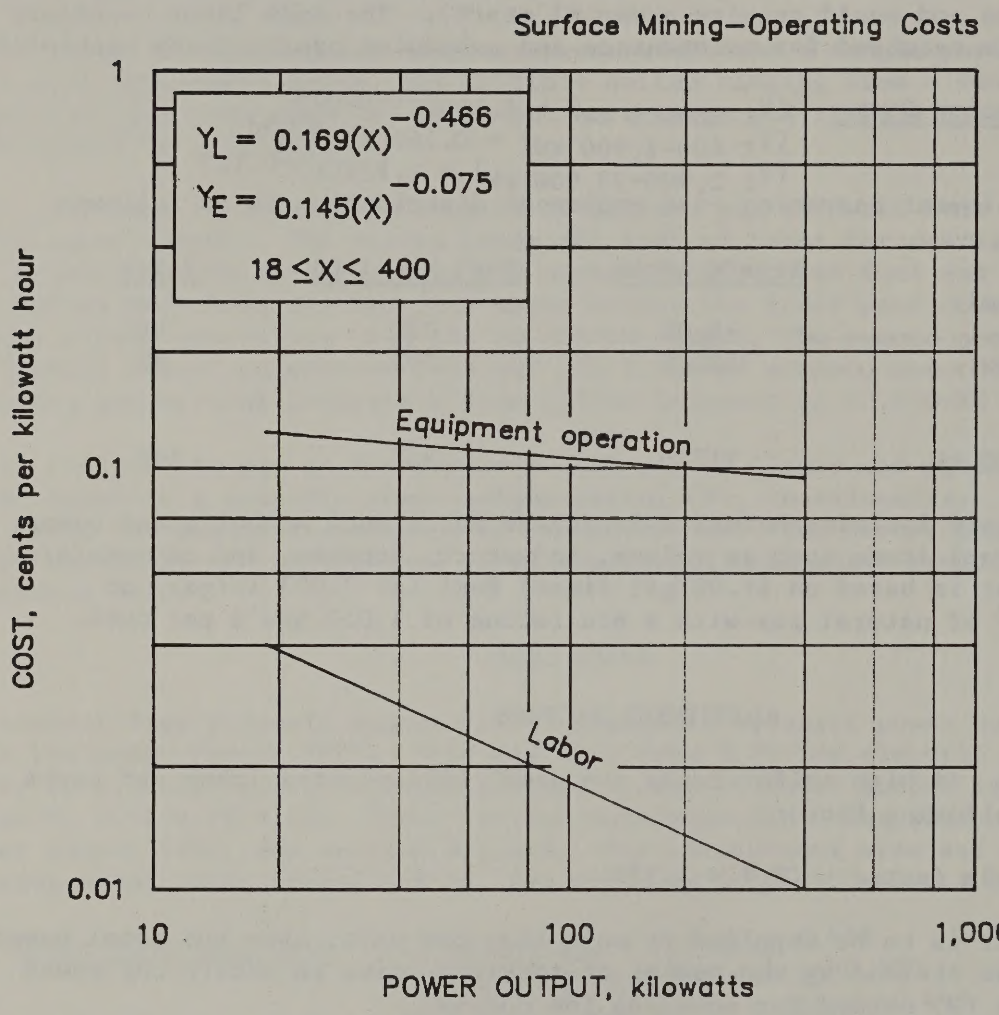
ADJUSTMENT FACTORS

Sulfur Fuels Factor If high sulfur fuels are used, multiply the labor and parts costs by the following factor:

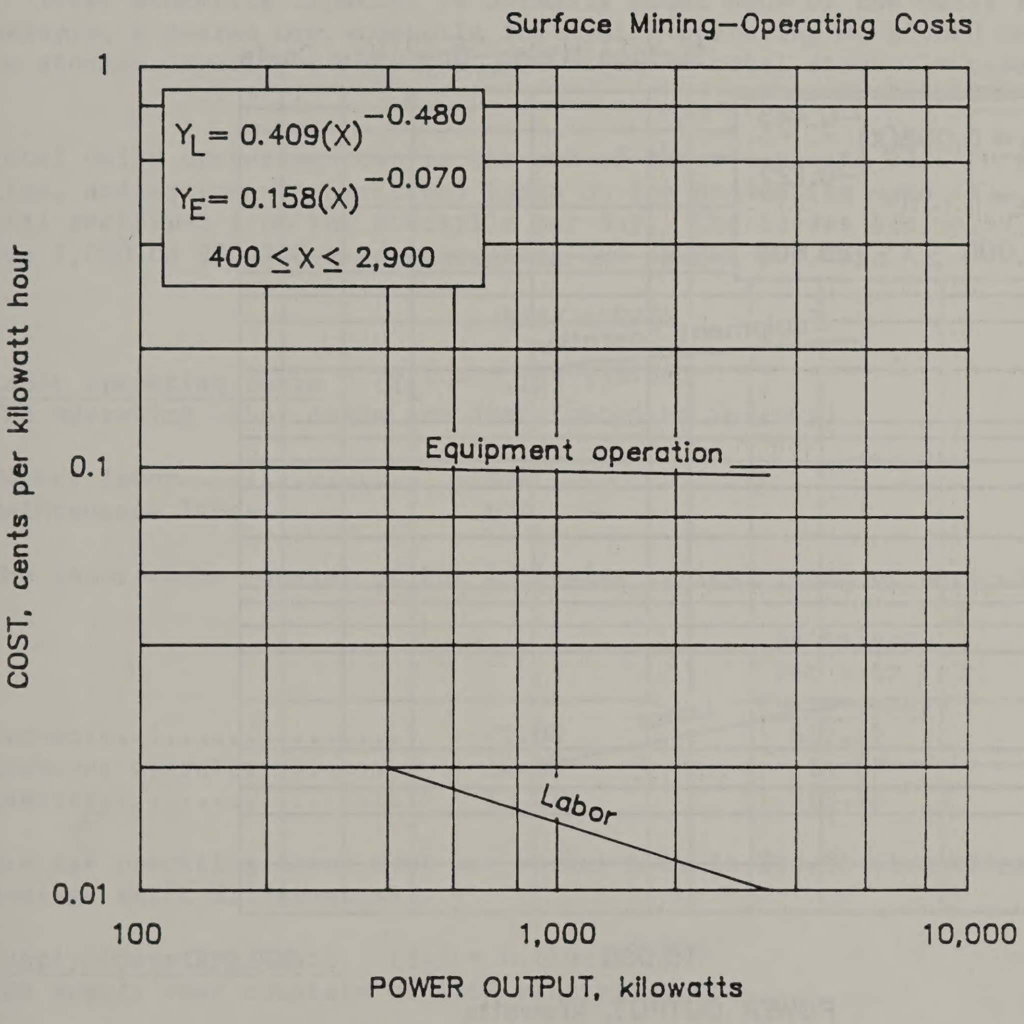
Sulfur fuels factor $(F_L) = 1.333$

Power Rate If power is to be supplied by more than one unit, then the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curves.

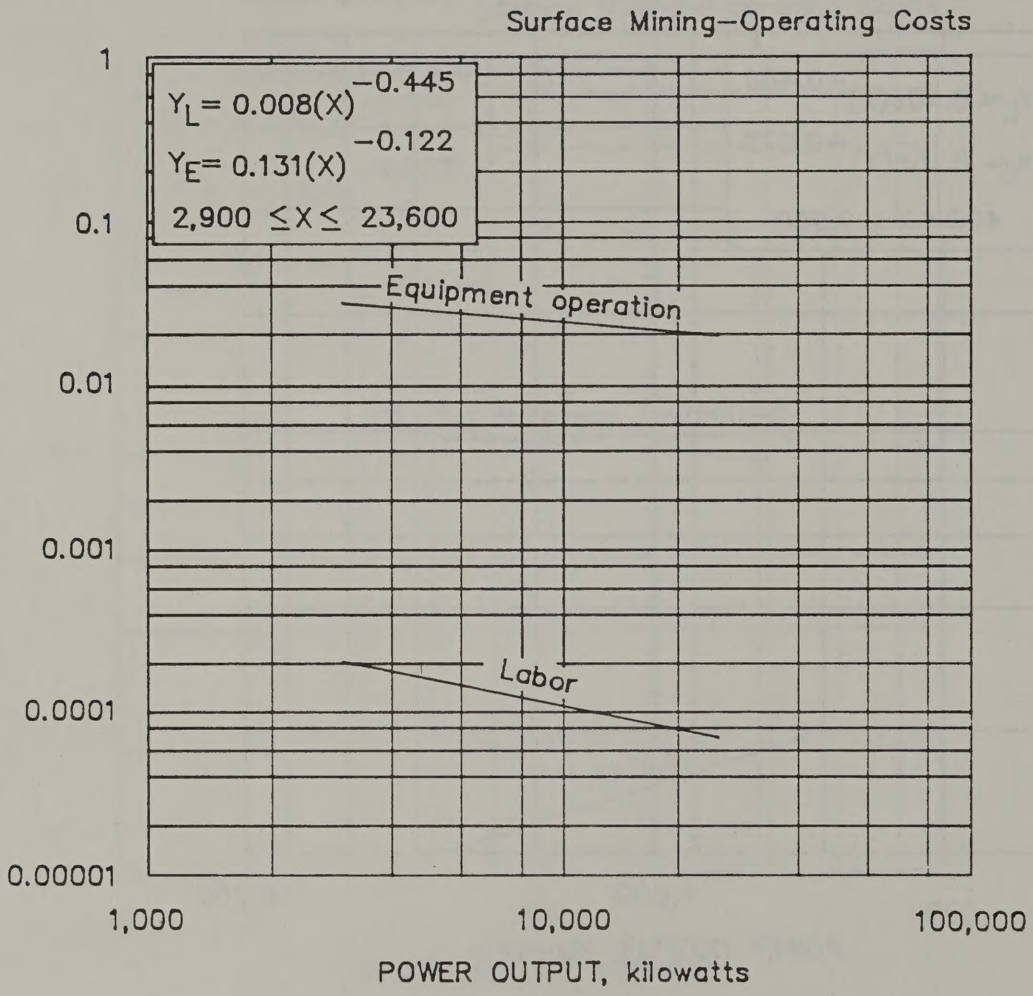
Power Source For those cases where power is supplied to the mine and mineral processing plant from different sources as a result of geographic or economic constraints, separate cost estimates, using this section, must be made to reflect the independent power outputs. This will result in different power costs for mines and mineral processing plants and must be accounted for separately in the mining and mineral processing sections of this manual.



3.2.4.6.a Portable power generation



3.2.4.6.b Portable power generation



3.2.4.6.c Portable power generation

3.2. SURFACE MINING - OPERATING COST

3.2.4. MINE PLANT GENERAL OPERATIONS

3.2.4.8. STOCKPILE STORAGE FACILITIES

Stockpile operating costs, as determined in this section, are based on metric tons of stockpiled material reclaimed during a two-shift-per-day operation. The costs represented are only applicable for stockpiles formed and reclaimed by conveyors. The daily reclaim rate is typically about 67% of the stockpile's live storage capacity. Total stockpile capacity is normally about 600% of the daily reclaim rate. For example, a coarse ore stockpile for a mill operating at 10,000 mtpd of ore has a live storage capacity of about 15,000 mt and a total stockpile capacity of 60,000 mt.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons material reclaimed from the stockpile per day. The curves are valid for operations between 2,000 to 200,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 7.229(X)^{0.503}$
The operating labor costs are distributed as follows:

Direct labor...............	33%
Maintenance labor..........	67%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic...................	72.0%	$17.99
Conveyor operator..........	14.8%	14.89
Laborer....................	13.2%	13.26

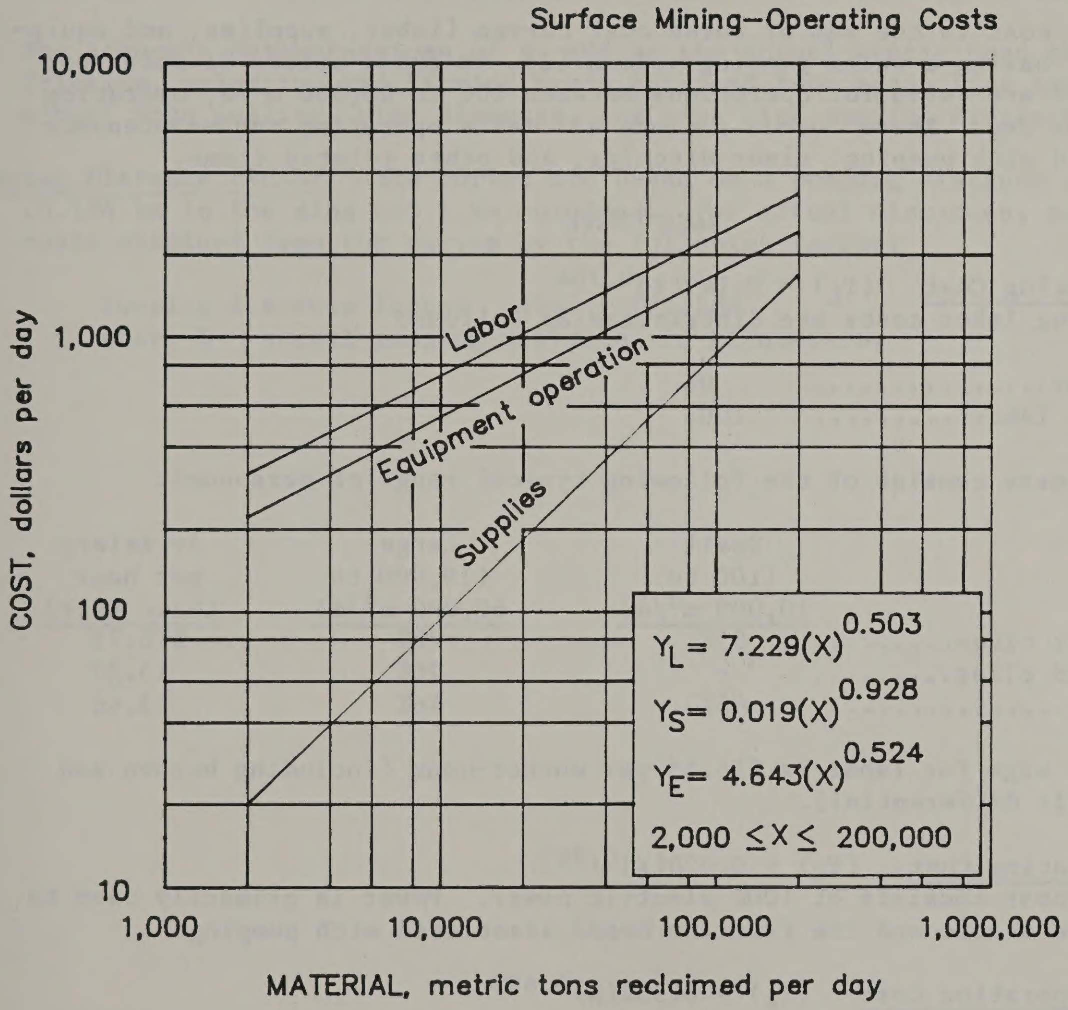
Average operating labor cost per worker-hour is $16.91 (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.019(X)^{0.928}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 4.643(X)^{0.524}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTOR

Shift-Reclaim Rate If a stockpile facility is operated one shift per day, multiply the daily reclaim rate by two; calculate the operating costs from the base curves using the adjusted reclaim rate; then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operated three shifts per day, multiply the daily reclaim rate by 0.67; calculate the operating costs from the base curves using the adjusted reclaim rate; then increase the calculated cost by 50% to arrive at the adjusted cost.



Surface Mining—Operating Costs

3.2.4.8. Stockpile storage facilities

3.2. SURFACE MINING--OPERATING COST

3.2.4. MINE PLANT GENERAL OPERATIONS

3.2.4.10.1. WATER AND DRAINAGE SYSTEM
DRAINAGE AND DISPOSAL SYSTEM

The curves apply to the most common dewatering method, which consists of pumping and disposing of water out of the mine. The curves are valid for an adjustable pumping head and distance of 110 m and 1.184 km, respectively.

The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) having a water-pumping volume (X), in cubic meters of water per day. The curves are valid for operations between 100 to 60,000 m^3/d, operating three shifts per day. These curves include all daily operating and maintenance costs associated with pumping, minor ditching, and other related items.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.149(X)^{0.704}$
The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

The labor costs consist of the following typical range of personnel:

	Small (100 to 10,000 m^3/d)	Large (10,000 to 60,000 m^3/d)	Av salary per hour (base rate)
Mechanic 1st class.........	55%	28%	$16.78
Mechanic 2nd class.........	-	26%	15.89
Helper.....................	45%	46%	13.66

The average wage for labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.020(X)^{0.995}$
The supply cost consists of 100% electric power. Power is primarily used to overcome the static and the friction heads associated with pumping.

(E) Equipment Operation Cost $(Y_E) = 0.352(X)^{0.693}$
The equipment operating cost consists of 97% minor parts and 3% lubrication with the daily cost related to pumping and minor pipe line, ditch, and sump maintenance.

ADJUSTMENT FACTORS

Pumping Head Factor The operating cost curves are based on 100-m static head (lift) and 10-m friction head (in a standard new steel pipe line). For actual heads, multiply the costs obtained from the curves by the following factor:

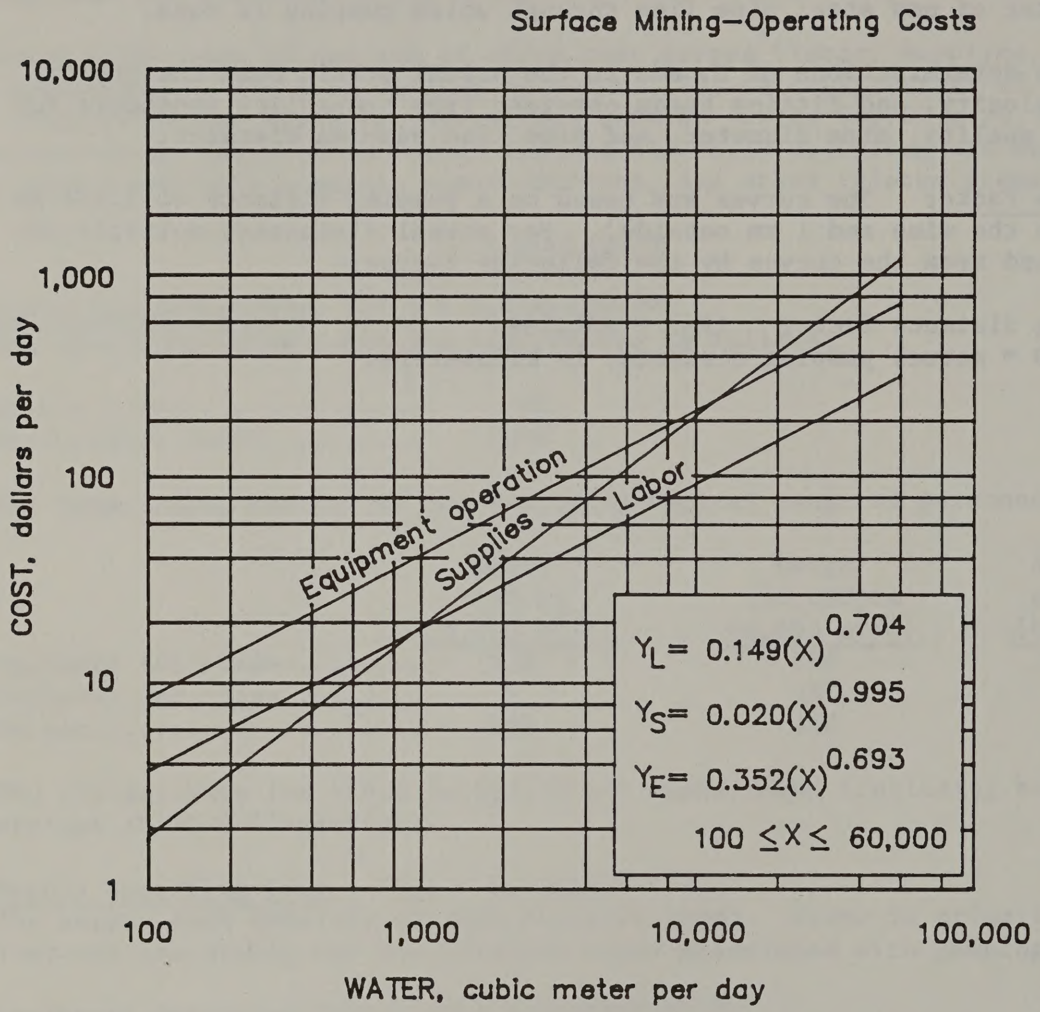
Pumping head factor $(F_H) = H/110$
where H = actual head (static, friction, velocity, and fitting), in meters.

For preliminary estimates of H, add to the actual static head (lift) 8 ms for each kilometer of new steel pipe line through which pumping is done.

For accurate determinations of H, add to the actual static head the sum of friction, velocity, and fitting heads obtained from hydraulics handbooks for actual pipe quality, pipe diameter, and pipe line pumping distance.

Pumping Distance Factor The curves are based on a pumping distance of 1.184 km (0.184 km in the mine and 1 km outside). For actual distances, multiply the costs obtained from the curves by the following factor:

Pumping distance factor $(F_D) = D/1.184$
where D = actual pumping distance, in kilometers.



3.2.4.10.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

3.2. SURFACE MINING--OPERATING COST

3.2.4. MINE PLANT GENERAL OPERATIONS

3.2.4.10.2. WATER AND DRAINAGE SYSTEM WATER SUPPLY SYSTEM (MAKEUP WATER)

Water is used in surface mines for dust control on haulage roads and for equipment cooling. The water supply system operating cost for a surface mine (and/or an adjoining mineral processing plant, section 7.1.8.14.2., IC 9143) is based on daily water consumption.

The total daily cost is the sum of three separate curves (labor, supplies, and equipment operation) for a volume (X), in cubic meters of water per day. The curves are valid for operations between 1,000 to 150,000 m^3/d, operating three shifts per day. The curves cover all daily maintenance and operating costs associated with water wells, storage tanks, pipelines, and distribution.

These curves are valid for a total pumping head ranging from 260 to 330 m with an average of 291 m, and pumping distances ranging from 3 to 53 km.

To estimate mine water demand, multiply the daily mine capacity (ore and waste) by 0.07. The 0.07 factor is the approximate number of cubic meters of water required per metric ton mined.

For mines where slurry transportation is required and a high percentage of water is reclaimed (e.g., Florida phosphate mines), 0.16 to 0.23 m^3/mt of material slurried (dry weight) could be assumed to be a valid value for (X).

If the total daily volume (mine and processing plant makeup water) is known, the manual user should enter this volume in the equations given below (unless the processing plant is supplied with water from an independent source). The total daily cost may be alloted as follows[1]:

(a) 9% to section 3.2.4.10.2. (surface mine)

(b) 91% to section 7.1.8.14.2. (mineral processing, IC 9143).

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 1.937(X)^{0.445}$
The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

---

[1] Percentages derived from Bureau of Mines IC 8285 dealing with water consumption for U.S. mines and mineral processing plants. Different percentages may be used if an actual breakdown of mine and mineral processing plant water consumption is known.

The labor costs consist of the following typical range of personnel:

	Small (1,000 to 13,000 m^3/d)	Large (13,100 to 150,000 m^3/d)	Av salary per hour (base rate)
Mechanic-welder..........	25%	14%	$16.33
Pipefitter...............	34%	39%	22.80
Helper...................	41%	47%	13.66

The average wage for labor is $16.63 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.045(X)^{0.997}$
The supply cost consists of 100% electric power. Power is required to overcome the static head (well depth and lift) and pipeline head losses.

(E) Equipment Operating Cost $(Y_E) = 0.054(X)^{0.864}$
The equipment operating cost consists of 95% for parts and 5% for lubrication with the daily cost related to pipe lines, pumps, and storage tanks.

ADJUSTMENT FACTORS

Pumping Distance Factor To correct for actual pumping distance, D, multiply the costs obtained from the curves by the following factor:

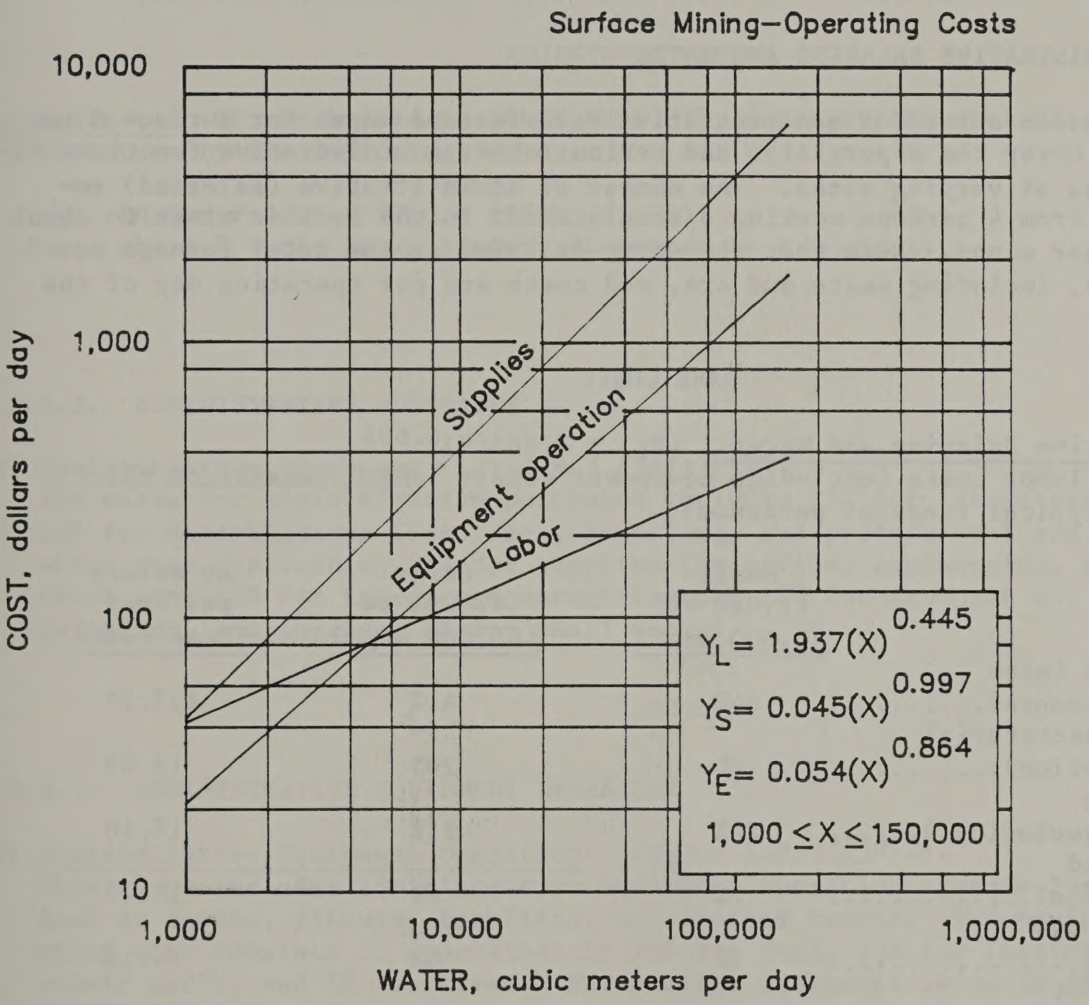
Pumping distance factor $(F_D) = 0.850+1.948(D)(X)^{-0.549}$
where X = daily volume, in cubic meters per day,
and D = actual distance, in kilometers.

Because a change in distance results in a change in friction head, also multiply the costs by the dynamic head portion (16%) of the factor, F_H.

Pumping Head Factor The curves are based on 244-m static head (well depth and lift) and a 47 m friction (dynamic) head. To adjust for actual total heads, H, multiply the costs obtained from the curves by the following factor:

Pumping head factor $(F_H) = H/291$
where H = the sum of static, friction, velocity, fitting, and discharge heads, in meters.

Purchased Water If water is purchased, estimate the labor, supply, and equipment operation costs (from the delivery point to the mine and processing plant) and add them to the purchasing cost.



3.2.4.10.2. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)

3.2. SURFACE MINING - OPERATING COST

3.2.5. GENERAL EXPENSES
ADMINISTRATIVE COSTS

These costs include expenses incurred in the everyday operation of the plant and do not include general company overhead. The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons ore and waste per day. The curves are valid for operations between 1,000 to 400,000 mtpd, operating three shifts per day.

3.2.5.1. ADMINISTRATIVE SALARIES AND WAGES

The general expense curve for administrative salaries and wages for surface mines is intended to cover the supervision and various other administrative functions required for mines of varying sizes. The number of administrative (salaried) employees varies from 4 persons working a single shift in the smaller mines to about 100 in the larger mines. Note that the curve is based on the total tonnage moved in a single day, including waste and ore, and costs are per operating day of the mine.

BASE CURVE

(L) Administrative Salaries and Wages $(Y_L) = 7.683(X)^{0.606}$
The direct labor costs (excluding equipment repair labor) consist of the following typical range of personnel:

	Small (1,000 to 40,000 mtpd)	Large (40,000 to 400,000 mtpd)	Av salary per hour (base rate)
Supervision (mine and maintenance)..........	44%	41%	$23.13
Clerical (secretarial and accounting)...........	18%	20%	13.69
Engineering (mining, geological)......	21%	21%	18.10
Assaying and metallurgical.............	7%	8%	14.43
Purchasing and warehousing................	7%	6%	14.12
Safety, first aid, security..............	3%	4%	18.85

The average wage for labor is $17.87 per worker-hour (including burden and average shift differential).

Selected median annual salaries are as follows (without burden):

Mine superintendent	$51,600
General mine foreman	34,800
General maintenance foreman	33,600
Chief electrician	40,900
Chief engineer	49,000
Engineers and geologists	35,900
Chief accountant	42,000
Safety director	35,900
Director of purchases	42,000
Secretaries, clerks	13,900

ADJUSTMENT FACTOR

Burden Factor If the burden is other than 32%, multiply the cost obtained from the curve by the following factor:

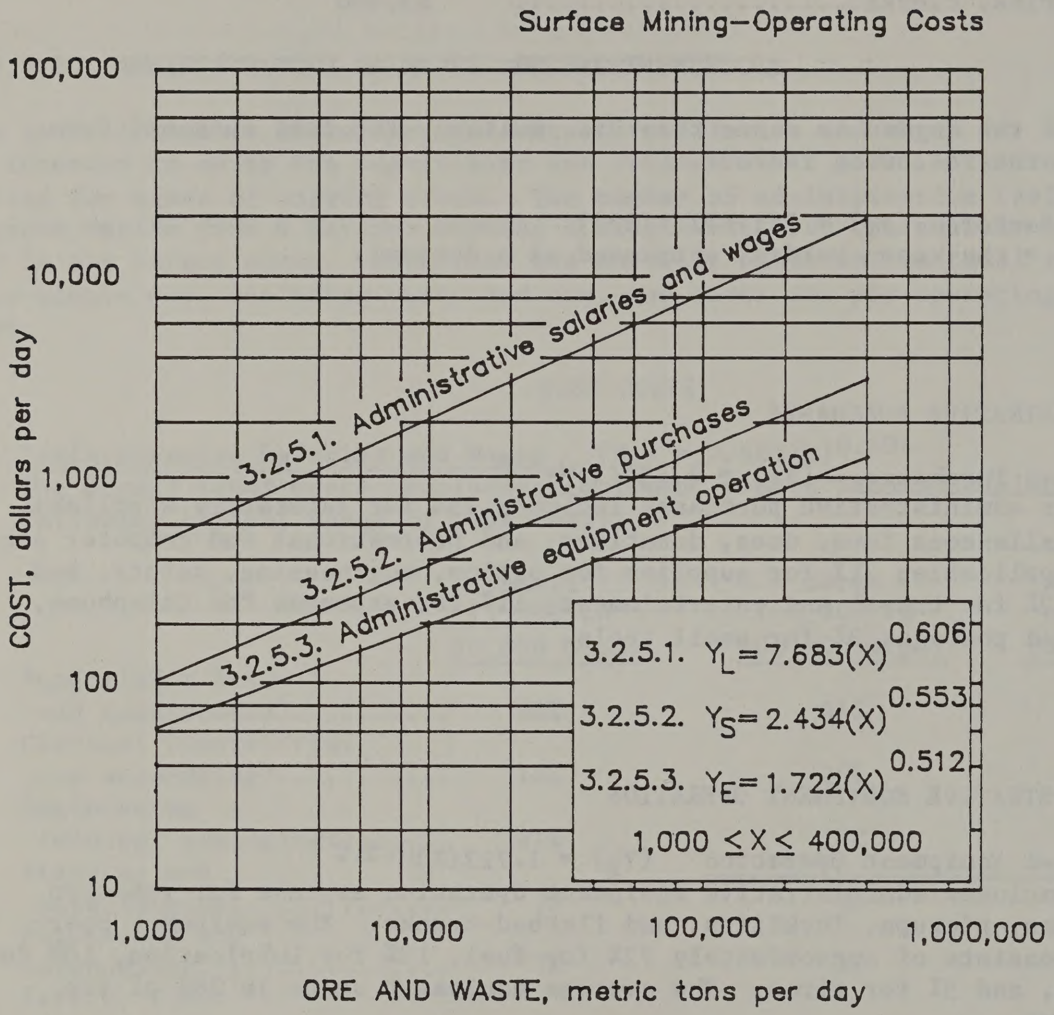
Burden factor $(F_L) = [(1+B)/(1.32)]$
where B = the known burden, expressed as a decimal.

3.2.5.2. ADMINISTRATIVE PURCHASES

(S) Administrative Purchases $(Y_S) = 2.434(X)^{0.553}$
The curve for administrative purchases includes 25% for laboratory supplies; 23% for miscellaneous fees, dues, donations, and professional and computer services when applicable; 21% for supplies for office, engineering, safety, and first aid; 12% for travel and entertainment; 11% for expenses for telephone, telegraph, and postage; 8% for small tools.

3.2.5.3. ADMINISTRATIVE EQUIPMENT OPERATION

(E) Administrative Equipment Operation $(Y_E) = 1.722(X)^{0.512}$
This curve includes administrative equipment operation expense for vehicles such as sedans, pickups, forklifts, and flatbed trucks. The equipment operating cost consists of approximately 72% for fuel, 13% for lubrication, 10% for repair parts, and 5% for tires. The average equipment usage is 26% of its available time.



3.2.5.1.—3. General expenses
ADMINISTRATIVE SALARIES AND WAGES
ADMINISTRATIVE PURCHASES
ADMINISTRATIVE EQUIPMENT OPERATION

3.2. SURFACE MINING--OPERATING COSTS

3.2.6. INFRASTRUCTURE

3.2.6.3. TOWNSITE-CAMPSITE

CAMPSITE

Where conditions such as remote location or seasonal operation require a single-status campsite (i.e., room, board, and recreation facility), the daily operating cost should be derived from the following base cost curve. Today a caterer is usually employed to provide board, housekeeping, and recreation supervision. Heat, lights, garbage disposal, and plant maintenance are usually provided by the owner.

BASE CURVE

The total daily cost is derived from the supply curve based on the total number of persons who occupy the campsite (X). The curve is valid for campsites occupied by 20 to 1,000 persons. All persons receive both room and board.

(S) Supply Operating Cost $(Y_S) = 37.143(X)^{0.897}$

	Small (20 to 450 persons)	Large (450 to 1,000 persons)
Board......................	61.5%	59.0%
Housekeeping and recreation	23.9%	23.0%
Heat.......................	6.4%	9.0%
Light......................	2.4%	3.4%
Maintenance................	5.8%	5.6%

If the number of persons requiring board varies from the number of persons requiring room, use the following equation:

(S) Supply Operating Cost $(Y_S) = [37.143(X)^{0.897}][0.60(B/R)+0.40(R)]$

where B = number of persons requiring board only,
and R = number of persons requiring room only.

These curves are based on a caterer who provides all necessary personnel for food service, housekeeping, distribution and collection of mail, monitoring recreation, etc., and all necessary supplies, such as pots, pans, dishes, silverware, sheets, pillow cases, blankets, waste cans, recreation supplies, janitorial supplies, food, etc. The evaluator must add the cost for local, State, or Federal taxes where required.

ADJUSTMENT FACTORS

Owner-Operator Factor When the facility is owner-operated rather than catered, multiply the cost obtained from the curve by the following factor:

Owner-operator factor $(F_O) = 0.93$

Diesel Power Factor When the electric power is provided by a diesel-electric system rather than a power line grid, multiply the cost obtained from the curve by the following factor:

Diesel power factor $(F_D) = 1.04$

TRAILER COURT

Where conditions such as remote location or lack of available housing require installation of a family trailer court complete with utilities, laundromat, recreation facilities, blacktop driveway, and possibly swimming pool, the daily operating cost should be derived from the following two curves. The total daily cost is derived from the supply curve, based on the total number of trailer spaces, (X), required. The curve is valid for trailer courts with 20 to 1,000 units.

BASE CURVE

The curves are based on trailer and facility maintenance, insurance, casualty insurance, supervisory and worker wages, plus overhead, heat, and lights.

(S) Supply Operating Cost $(Y_{S\ FREE}) = 49.514(X)^{0.590}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are free to supervisors and workers. The company pays all operating costs on the facility.

(S) Supply Operating Cost $(Y_{S\ RENTED}) = 1{,}676.049(X)^{-0.716}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are rented to supervisors and workers. The company pays for any loss on the facility.

ADJUSTMENT FACTORS

Swimming Pool Factor When the trailer court does not provide a swimming pool, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Swimming pool factor $(F_{P\ FREE}) = 0.82$

When the spaces and trailers are rented and the trailer court has 52 or more units it will show a profit. If there are less than 52 units multiply the curve $(Y_{S\ RENTED})$, by the following factor:

Swimming pool factor $(F_{P\ RENTED}) = 0.05$

Trailer Space Rental Factor When the occupants rent trailer space for their own trailers, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Trailer space rental factor $(F_{R\ FREE}) = 0.36$

PERMANENT HOUSING

Company totally owned and operated townsites are decreasing in number because of their high cost and persistent social problems. The trend seem to be toward small family housing facilities combined with an existing nearby city.

Large townsite permanent housing:
Today, the military appears to be the greatest user of this type of facility. The Air Force provides housing to its officers and enlisted personnel. The Government pays for housing and facility maintenance, all utilities, supervisor, and worker labor, etc. The average operating costs for 1983 were:

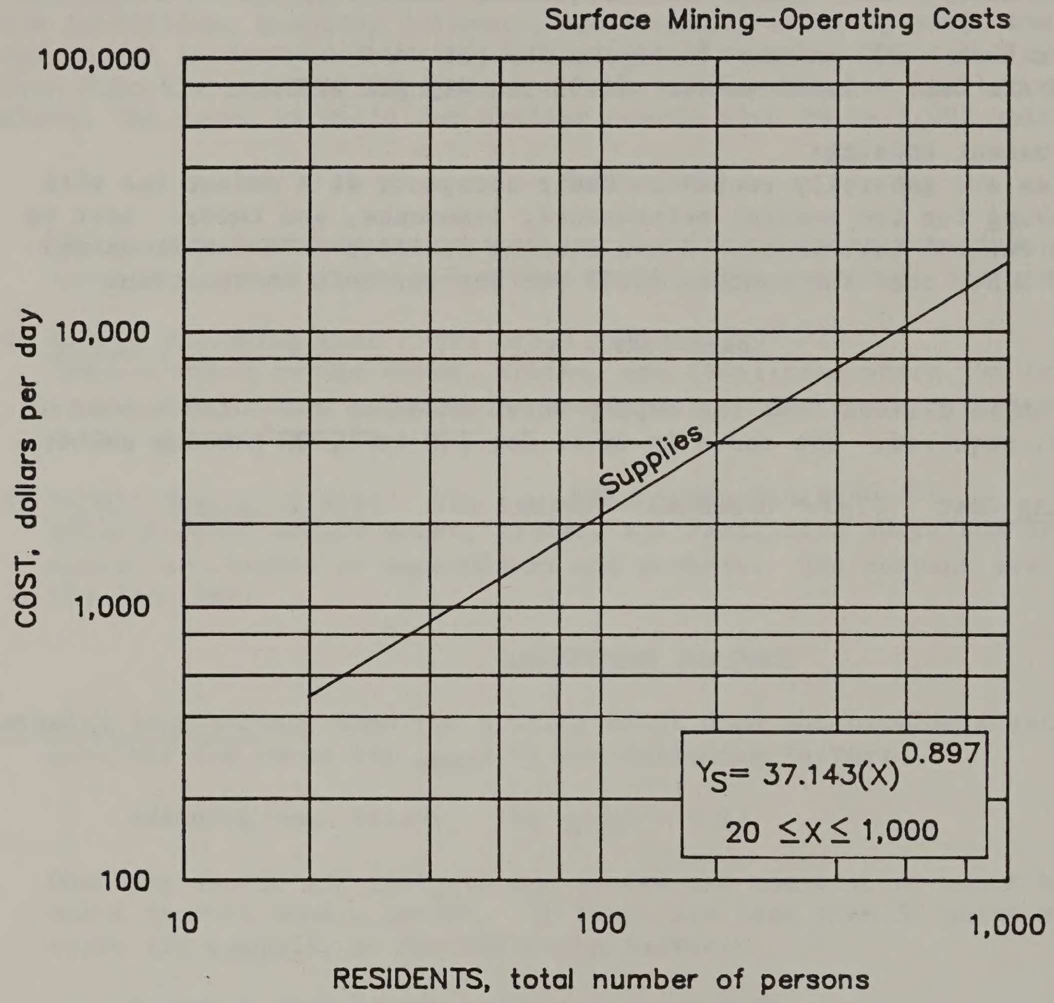
McCord Air Base - 993 units: \$6.66 per day per unit
Fairchild Air Base - 1,580 units: \$6.93 per day per unit

Small townsite permanent housing:
These facilities are generally rented to their occupants at a modest fee with the company paying for the general maintenance, insurance, and taxes. Rent is applied to the capital investment. A new housing facility (175 family units) in the western U.S., cost the company \$0.98 per day per unit to maintain.

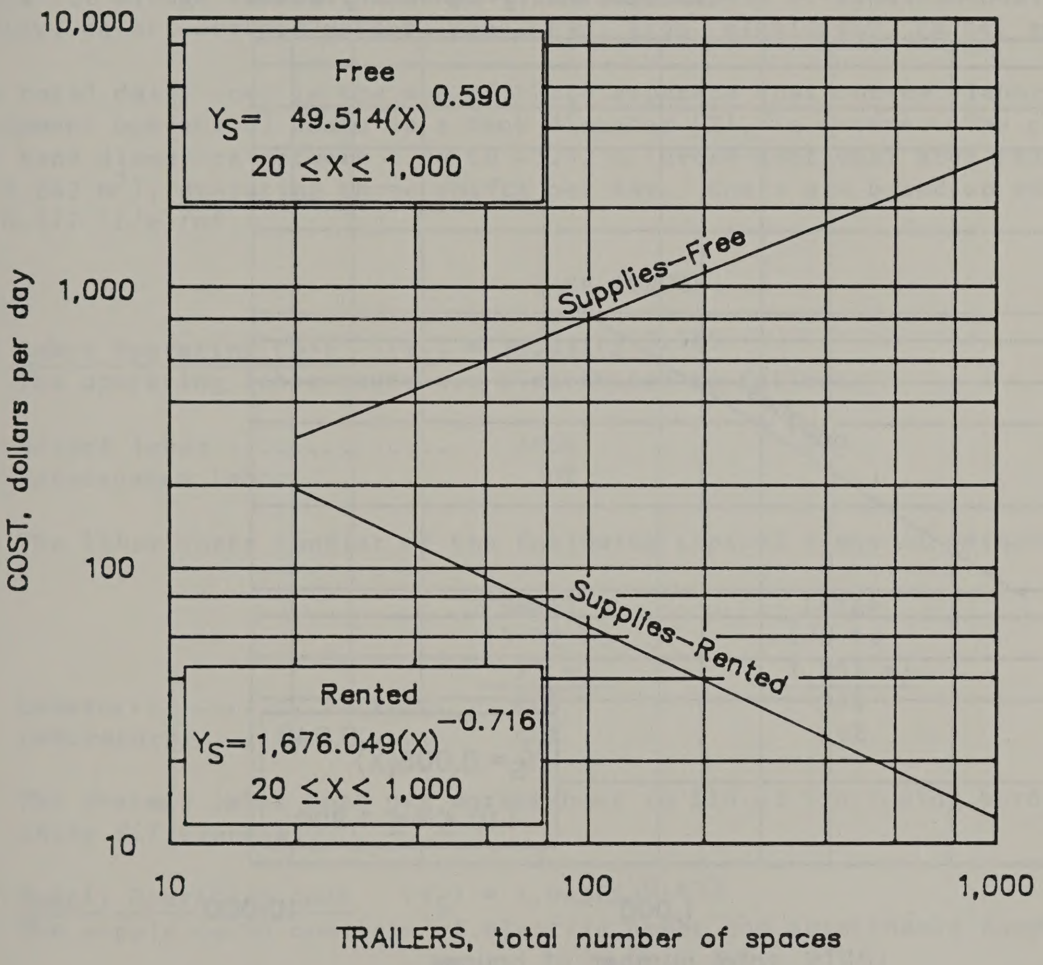
BASE CURVE

The total daily cost is derived from the supply curve based on the total number of housing units, (X), required. The curve is valid for 140 to 1,900 housing units.

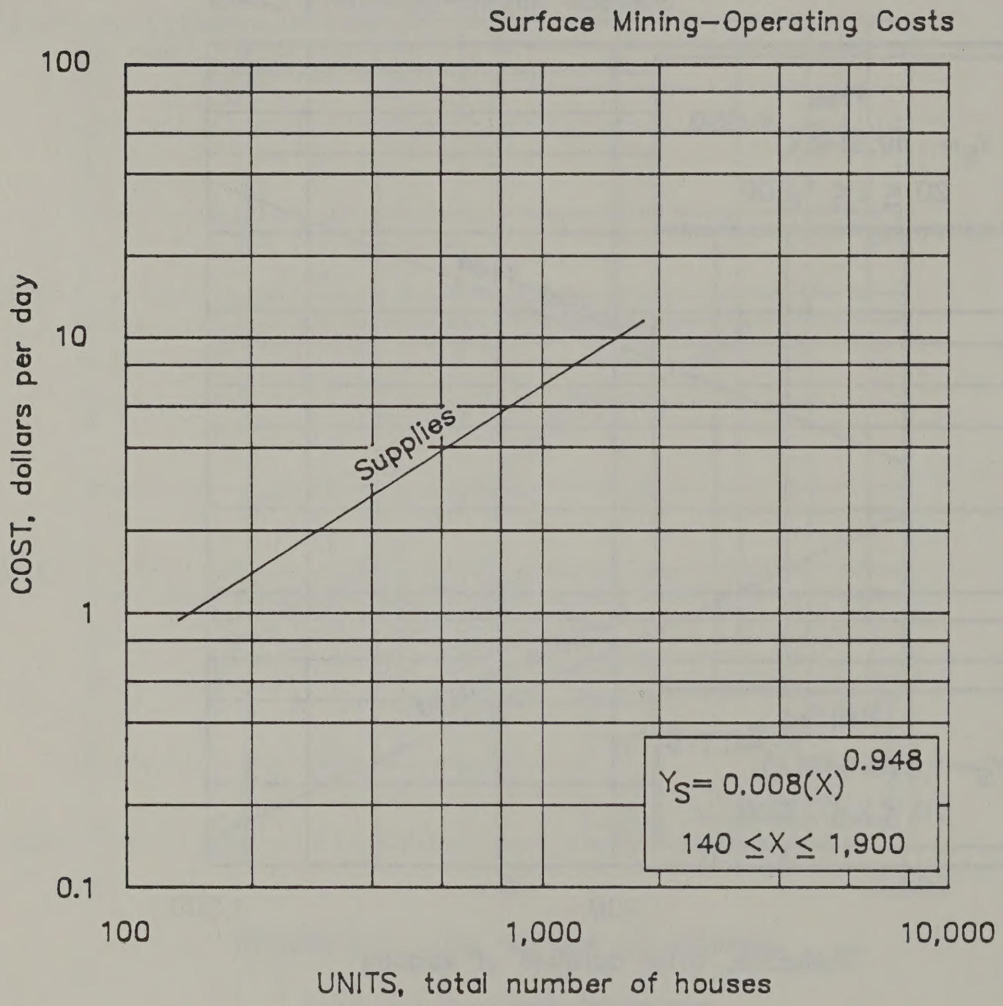
(S) Supply Operating Cost $(Y_S) = 0.008(X)^{0.948}$



3.2.6.3.a Townsite-Campsite
CAMPSITE


Surface Mining—Operating Costs

3.2.6.3.b Townsite-Campsite
TRAILER COURT



3.2.6.3.c Townsite-Campsite
PERMANENT HOUSING

3.2.6. INFRASTRUCTURE

3.2.6.4.1. WASTE WATER TREATMENT CLARIFICATION

This operation is a solids-contact clarifier used for water clarification by precipitation and/or coagulation. This cost curve is for removal of suspended solids formed after final neutralization of out-of-pipe effluent. The curve includes all principal costs associated with the operation of the unit. It does not include costs for sludge removal. The unit can selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, alkalinity, taste, and odor.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a tank diameter (X), in meters. The curves are valid for tank diameters between 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2), operating three shifts per day. Costs are based on an overflow rate of 0.377 (L/s)/m^2.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 38.931(X)^{0.119}$
The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

	Small (5.72 to 75 m)	Large (75 to 1,661 m)	Av salary per hour (base rate)
Laborer....................	60%	54%	$13.66
Laboratory.................	40%	46%	15.89

The average labor cost per worker-hour is $14.43 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.083(X)^{0.633}$
The supply curve consists of electric power and maintenance supplies.

	Small (5.72 to 75 m)	Large (75 to 1,661 m)
Electric...................	60%	34%
Maintenance................	40%	66%

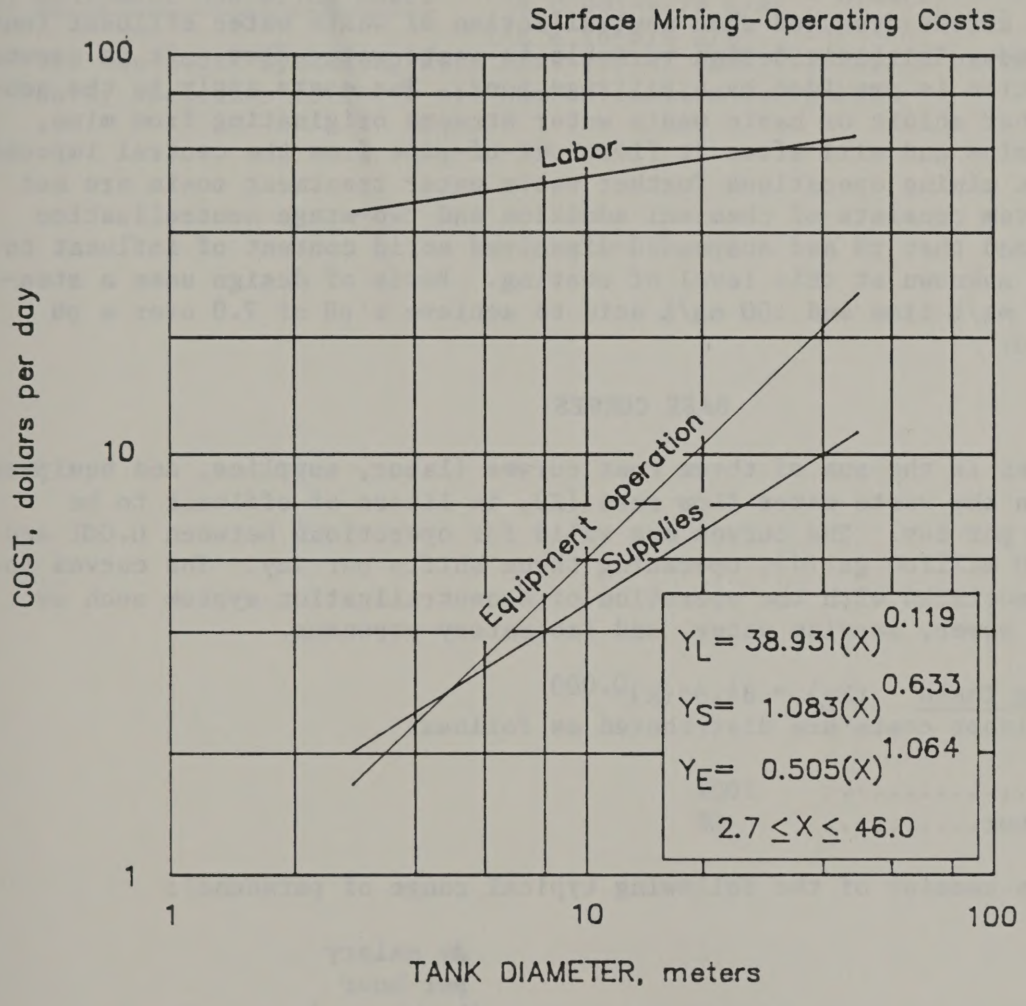
(E) Equipment Operating Cost $(Y_E) = 0.505(X)^{1.064}$
The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all clarification equipment.

ADJUSTMENT FACTORS

Flocculant Factor Normally, additional flocculants are not needed in the mine waste water treatment after neutralization. However, if polymers are needed or used, add the following factor to the supply cost obtained from the curve:

Supply factor $(F_S) = 0.334(D)^{1.812}$
where D = clarifier tank diameter, in meters.

The polymer is based on a standard dosage of 1.5 mg/L influent and an average polymer cost of $2.10/lb.



3.2.6.4.1. Wastewater treatment
CLARIFICATION

3.2.6.4.2. WASTE WATER TREATMENT NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to that manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in the EPA manual.

The operating cost curves are used when neutralization of waste water effluent (out-of-pipe) is required. The basic design variable is waste water flow. It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) based on the waste water flow rate (X), in liters of effluent to be treated per second per day. The curves are valid for operations between 0.001 and 876 L/s (22.8 to 20 million gal/d), operating three shifts per day. The curves include all costs associated with the operation of a neutralization system such as labor, lime, acid, power, service water, and laboratory expenses.

(L) Labor Operating Costs $(Y_L) = 84.85(X)^{0.000}$

The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Laborer....................	89%	$15.80
Laboratory.................	11%	15.80

The average labor cost per worker-hour is $15.80 (including burden and average shift differential).

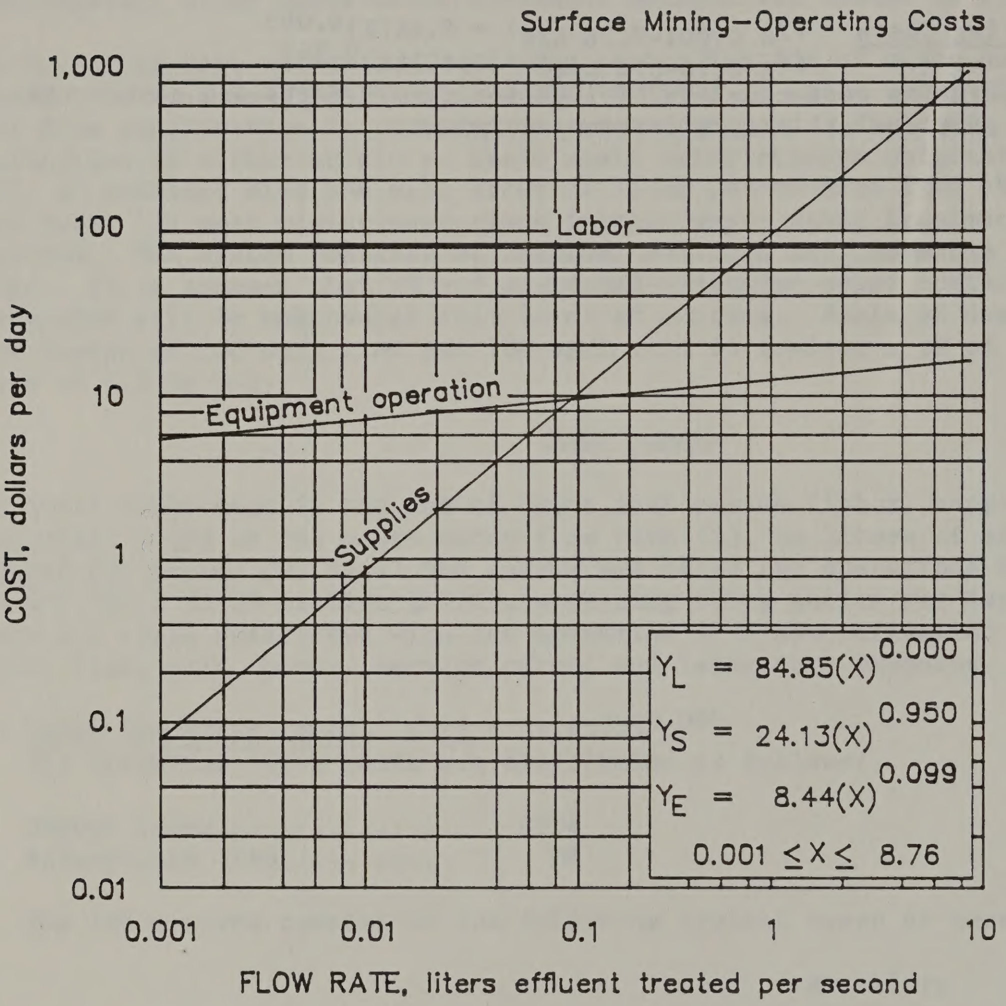
(S) Supply Operating Costs $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 24.13(X)^{0.950}$
$(Y_{S\ 8.76\text{-}876\ L/s}) = 21.282(X)^{0.997}$

The supply costs consists of electric power, water, and chemicals and lime in the following proportions:

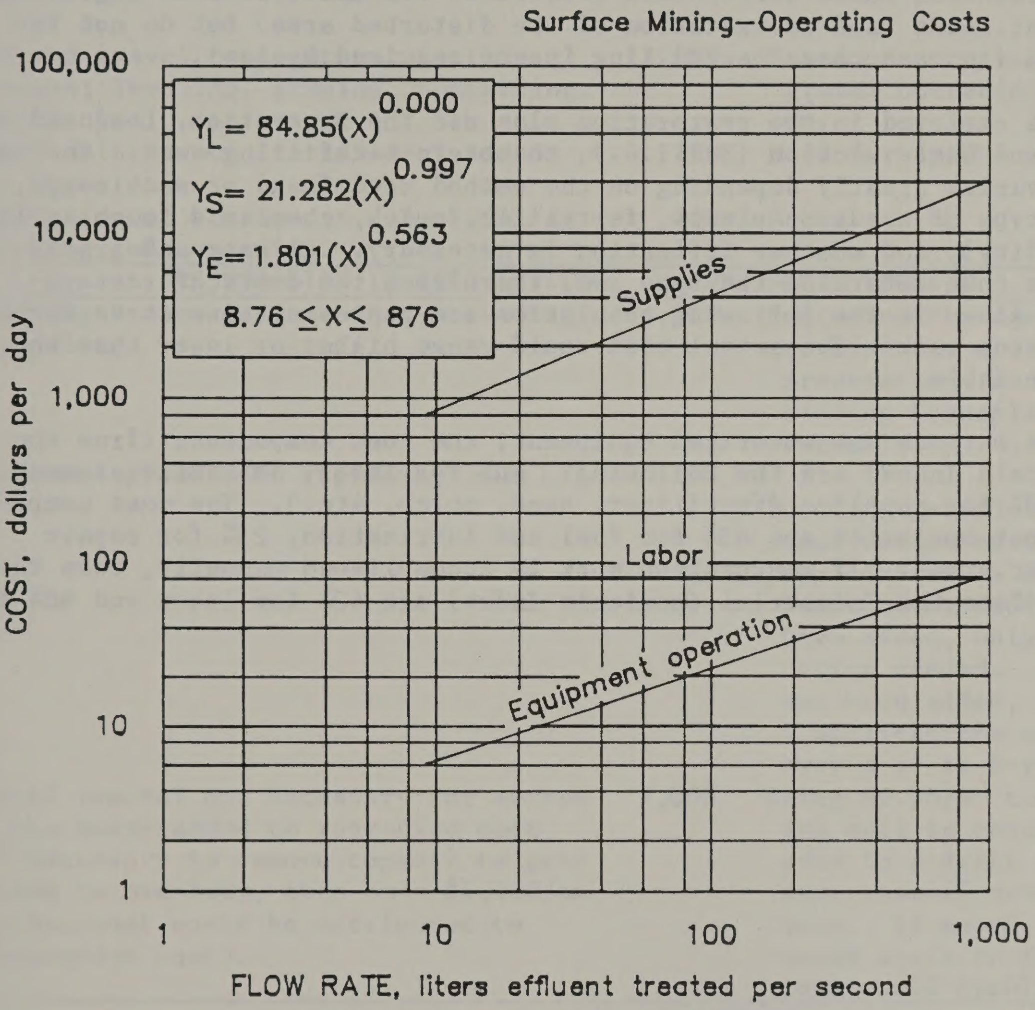
	Small (0.001 to 8.76 L/s)	Large (8.76 to 876 L/s)
Electric power.............	3%	2%
Water......................	80%	89%
Chemicals and lime.........	17%	9%

(E) Equipment Operating Costs $(Y_{E\ 0.001\text{-}8.76\ L/s}) = 8.44(X)^{0.099}$
$(Y_{E\ 8.76\text{-}876\ L/s}) = 1.801(X)^{0.563}$

The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all neutralization equipment.



3.2.6.4.2.a Wastewater treatment
NEUTRALIZATION



3.2.6.4.2.b Wastewater treatment
NEUTRALIZATION

3.2. SURFACE MINING--OPERATING COST

3.2.7. RESTORATION DURING PRODUCTION

Mine restoration is the process of initiating and accelerating the natural continuous trend toward recovery (stabilization, etc.), the type of environment (desert, flatland, grasslands, mountains, etc.) and the restoration requirements by law in any given State (which range from none to very strict). Some states require permits prior to disturbing the ground surface. Typically, the permit specifies that the area must be reclaimed, hectare for hectare, to a use similar to the prior use or other beneficial use. Most restoration activities for mines include regrading and leveling plant sites (and revegetation of the disturbed area) but do not include backfilling (in most cases backfilling is not required by law).

If backfilling is employed in the restoration plan use the Excavation, Load and Haul Overburden and Waste section (3.2.1.4.), to obtain backfilling cost. The revegetation cost varies greatly depending on the method used (hand or machinery), materials used, type of seeds or plants, fertilizer, mulch, chemicals (such as lime for reducing acidity), and whether irrigation is necessary. Climate and ground slope are factors that determine the type and, therefore, the costs of restoration. The costs given in the following tabulation are representative costs for a specific restoration task. The actual cost could range higher or lower than the cost given in the table.

Where restoration methods use motorized equipment, the cost components (from the Industrial Chemicals Index) are the following: 40% for labor, 40% for equipment operation, and 20% for supplies (fertilizer, seed, mulch, etc.). The cost components for equipment operation are 65% for fuel and lubrication, 25% for repair parts, and 10% for tires. If restoration work is accomplished manually, then the cost components (from the Industrial Chemicals Index) are 60% for labor and 40% for supplies.

COST COMPARISONS OF RESTORATION METHODS

	Cost per hectare	Remarks
SPECIFIC RESTORATION WORK (INDEPENDENT OF CLIMATE OR GEOGRAPHY)		
Revegetation on steep slope--roadside slopes, tailing slopes, or waste dump slopes, using hydroseeder with fiber mulch.	$1,000-1,500	Based on using 18 kg/ha of seed, 73 kg/ha of fertilizer, and expenses to use a boom crane, pickup truck, 2 equipment operators, and a swamper.
Transplanting trees or shrubs by hand on moderate to steep slopes.	5,000	Assume 2,500 trees hand planted per hectare at $2 per tree or shrub.
Sand and gravel restoration, includes placers; leveling, grading, topsoiling, reseeding.	3,000	Based on a typical sand-and-gravel operation near Denver, CO.
Annual maintenance (fertilizers added for above).	160	Cost for applying fertilizer.
Restoration of borrow pit - backfilling leveling and reseeding.	400-600	None.
RESTORATION IN HIGH ALTITUDE (MOUNTAINOUS) TERRAIN		
Regrading and reseeding - not including topsoiling.	$4,000	Regrading for adequate drainage to minimize erosion, seedbed preparation, and reseeding (including transplanting trees and shrubs).
Maintenance (added to regrading cost).	130	Purchasing-applying fertilizer--application cost for 1 yr. If application is on area where at least 30-cm depth of topsoil has been added, only 1 year's application needed. If topsoil has not been added, then as many as 4 applications may be required over a 6- to 8-year period.
Topsoil removal not necessary for access to ore body--added to regrading cost (if necessary to remove topsoil to gain access to ore body, then only $1,300/ha of this cost would be attributed to restoration cost).	7,000	Using \$2.30/m^{3} cost of stockpiling soil to cover a disturbed area to a depth of 30 cm. Assume topsoil moved and emplaced once. If moved, then stored and moved again to final placement, cost could double).
RESTORATION IN ARID AND SEMIARID LANDS		
Soil added	$5,000	Required to achieve restoration on only the most severely disturbed sites. Generally serves to accelerate the rate of achieving permanent self-sustaining vegetation.

COST COMPARISONS OF RESTORATION METHODS--Continued

	Cost per hectare	Remarks
RESTORATION IN ARID AND SEMIARID LANDS--Continued		
Seeding and irrigation in arid climate on tailings dams, waste dump sites, road slopes.	$12,000-15,000	Irrigation system cost (sprinkler or drip tube) is estimated at $8,000/ha. Water assumed to be pumped on site at annual rate of 12,000 to 18,000 m^3/ha at $63 to $67 per 1,000 m^3 of water.
Seed and fertilizer broadcast on surface --no soil coverage or mulch.	700	Minimum slope where seed will cover naturally with soil. Seed broadcast manually.
Hydromulching with 680 kg wood fiber per hectare plus seed and fertilizer.	1,900-2,500	Most common southwestern U.S. hydromulch mix; will hold seed and fertilizer in place on steep and smooth slopes.
Straw or hay broadcast with straw blower on surface at 3,400 kg/ha.	2,500	Very effective as energy absorber and mulch. Not used on steep slopes. Cost increase significant if slopes over 14 m from access.

4.1. UNDERGROUND MINING--CAPITAL COSTS

4.1.1. EXPLORATION

Exploration costs and data were partly derived from mining and exploration companies and contractors. However, credit is given to Mr. William Salisbury of Salisbury and Dietz, Spokane, WA, for his generous supply of data and overall review.

Exploration can be defined as all the activities and evaluations performed in order to locate and define mineral deposits for the purpose of extraction now or in the future.

Exploration covers a wide range of activities from that of a prospector searching for mineral outcrops to the sophisticated equipment in ground or airborne surveys attempting to detect hidden mineral deposits, followed by extensive sampling and logging of excavations or drilling programs.

An organized exploration program consists of the four following principal stages:

Stage 1. Regional Appraisal
Stage 2. Detailed Reconnaissance of Favorable Areas
Stage 3. Detailed Surface Appraisal of Target Areas
Stage 4. Detailed Three-Dimensional Sampling and
Preliminary Evaluation

Costs in this section are directed to those related to exploration activity at the level of "project" status. The point where a company's general exploration program is elevated to "project" status will differ from company to company (or project), but in general this transition is marked by such activity as land purchase or lease, claim staking, geophysical and geological surveys, drilling, etc. In any case, exploration expenditures and efforts increase dramatically over a small unit area. Labor costs are the major cost component and drilling is most often the principal cost item for a project. Exploration costs will range widely depending on methods used, size of project, commodity sought, remoteness, terrain and vegetation conditions, weather, geologic complexity, etc.

Detailed Surface Appraisal of Target Areas

If the results of the detailed reconnaissance are favorable, they may indicate areas ranging in size from 3 to 130 km^2 where more detailed in- vestigation is warranted. This stage of investigation would include all of the ground survey techniques or methods which were used in stage 2, but with more refinement, closer intervals, and greater detail. The methods or techniques used might include additional outcrop examination, geologic mapping, boulder tracking, rock and specialized sampling, and possibly assaying. In addition, the various ground geophysical studies including gravity, magnetic, radiometric, seismic, resistivity, self-potential, and induced polarization would be made. Possibly, this stage would also warrant some trench excavation and drilling, plus field and laboratory tests. Unit costs for the various techniques or methods are given in the exploration tabulation.

Detailed Three-Dimensional Sampling and Preliminary Evaluation

A detailed three-dimensional survey or sampling of a target area ranging in size from 1 to 25 km^2 or more would be made if it appeared that an economical ore body existed. The sampling or survey would be made to determine boundaries or limits and depth, size, shape, mineralization, and grade. This stage of exploration would probably include an extensive drilling program together with borehole logging and geologic mapping. Excavation of test trenches, shafts, and adits might also be included. Samples would be taken, field and laboratory tests would be conducted, and assays would be made to permit econ- omic evaluations to be made. The cost of the stage 4 exploration could vary greatly depending on location, accessibility, ground cover, type of deposit, and the extent of a drilling or excavation program. Unit costs for various techniques or methods are given in the following tabulation.

Exploration

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geological Methods:				
Surface geological mapping.............	2 to 4 men	3 to 12/km^2	\$75 to \$275/km^2	Rate of production and cost depend on terrain, ground cover, complexity of geology, detail required, and scale of mapping.
Geological inference..			\$275 to \$760/d	A qualified geologist interpret data shown on maps, photographs, or field investigations.
Geophysical Methods:				
Gravitational survey..	1 geophysicist 2- to 3-man survey crew	12 to 50/ profile km	\$380 to \$1100/ profile km	Production varies from a few to 50 readings per day depending on type of equipment. Production also depends on station spacing and terrain. Surveying is the costly phase of method.
Magnetic Survey:				
Airborne...........	1 to 3 men		\$50 to \$90/line km plus \$2 to \$16/line km for interpretation	High sensitivity, helicopter, magnetic, electromagnetic, radioactivity surveys, etc., are usually taken concurrently from aircraft at 400 to 800 line km/d. Production and cost depend on type of aircraft equipment, etc.
Ground.............	2 to 3 men	4 to 6/ profile km	\$160 to \$180/ line km \$2.60 to \$2.90/ grid point	Production depends on precision, spacing, of readings and type of readings, type of equipment, weather, terrain, and mode of travel.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Seismic survey:				
0- 150-m depth........	2 to 7 men	1 to 4/depth determination	$35 to $110/depth determination	Portable equipment with 5 to 15 determinations per day.
150-m depth...........	15 to 20 men	5 to 10/depth determination	$180 to $270/depth determination	Vibroseis equipment with 3 to 15 depth determinations per day.
Very low frequency......	2 men		$315 to $385/line km.	Includes about $40/line km for interpretation.
Resistivity Survey......	1 geophysicist 1 to 4 asst.	2 to 3/depth determination	$57 to $114/depth determination	None.
Electromagnetic Survey:				
Airborne.............				Usually taken concurrently with magnetic and radioactivity surveys from 1 aircraft at 400 line km or 80 km^2/d.
Ground................	1 to 4 men	1 to 6/line km	$163 to $390/ line km	Readings taken at 25- 50-m intervals covering 5 to 10 km/d; dependent on on type of equipment, terrain, and mode of travel.
EMP..................	3 men		$4000/loop $1290/line km $2900/km^2	Parameters: Approximately 60-m by 120-m grid spacing; 430-m by 850-m loop; 10 lines, 15 stations/line; 10.3 km^2 costs include interpretation.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geochemical methods:				
Stream sediment sampling............	1 man		$\$19$ to $\$38/\text{km}^2$	Depends on sampling interval terrain, access, and mode of travel.
Reconnaissance soil sampling............	1 man	0.05 to 0.20/ sample	$11 to $24/sample	50 to 200 samples/d depending on access, terrain, ground cover, and geologic complexity.
Humus sampling......			$28 to $55/sample	None.
Biological sampling.			$28 to $55/sample	Do.
Water samples.......			$50 to $95/sample	Do.
Test pit:				
Trenching............				Depends on whether hand or equipment excavated.
Earth................	1 to 3 men	0.1 to $2.0/\text{m}^3$		$\$2$ to $\$55/\text{m}^3$
Do.				
Rock.................	3 men	0.2 to $3.5/\text{m}^3$		$\$11$ to $\$100/\text{m}^3$
Do.				

Helicopter cost and comparison

Manufacturer and model	Approx cost/h[1]	Passenger capacity[2]	Effective payload (h.o.g.e.[3]), kg		Cruise	
			Sea level	2700m	Speed, mph	Range, km
Hiller-Soloy 12-J...	$ 300	2	450	360	145	240
Bell-Soloy 47G3.....	305	2	500	360	145	350
Bell 206B..........	380	4	450	320	195	550
Hughes 500C.........	360	4	570	360	240	560
Hughes 500D.........	410	4	610	550	255	480
SUD Allouette Lama..	575	4	1,000	900	175	480
Bell 205...........	1,040	14[4]	2,100	1,100	195	210
Bell 214...........	1,855	15[4]	3,600	2,500	280	560

[1] Charter rate, includes fuel.
[2] Without pilot.
[3] Hovering out of ground effect.
[4] Varies, maximum capacity given.

Source: Modified and updated from William G. Salisbury.

Analytic costs

	Assay	Geochemical		Assay	Geochemical
Aluminum..........	$8.74	NAp	Lead..............	$4.96	$2.15
Antimony..........	8.98	$4.12	Lithium...........	7.42	NAp
Arsenic...........	10.36	4.32	Magnesium.........	9.11	3.30
Barium............	10.12	4.78	Manganese.........	6.60	3.12
Beryllium.........	12.10	NAp	Mercury...........	9.75	4.22
Bismuth...........	7.59	3.50	Molybdenum........	5.98	2.43
Cadmium...........	5.04	2.46	Nickel............	4.96	2.15
Chromium..........	7.75	4.28	Platinum..........	27.72	NAp
Cobalt............	5.46	2.15	Potassium.........	8.41	NAp
Copper............	4.96	2.15	Silica............	10.36	NAp
Copper oxide......	4.29	NAp	Silver............	8.45	2.81
Fluorine..........	NAp	5.73	Tungsten..........	11.02	5.72
Gold and silver...	9.07	NAp	Zinc..............	4.55	2.15
Iron..............	5.94	2.90			

NAp Not applicable.

NOTE--Sample preparation costs are assay--$1.85 and geochemical--$1.15. Semi-quantitative spectrographic analysis for 30 to 40 elements is $23.32.

Drill capacities (maximum, under ideal conditions)

Drill Model	- HOLE LENGTH, METERS (feet) -					Approx av weight lb (kg)
	EW	AW	BW	NW (Nc)	HW	
Truck mounted -hauled:						
Joy 22..........	NAp	NAp	900 (3000)	600 (2000)	NAp	4000 (1800)
Longyear 24......	270 (890)	220 (720)	NAp	NAp	NAp	1075 (490)
Longyear 34......	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	200 (700)[1]	3300 (1500)
Longyear 38......	NAp	940 (3100)[1]	700 (2400)[1]	580 (1900)[1]	370 (1200)[1]	3300 (1500)
Longyear 44......	NAp	1500 (5000)[1]	1200 (3940)[1]	936 (3070)[1]	716 (2350)[1]	5100 (2300)
Diamond Drill DDC	NAp	550 (1800)	500 (1650)	300 (1000)	NAp	1900 (860)
CP 670 Rotary....	NAp	NAp	NAp	NAp	+300[2] (+1000)[2]	
Helicopter transportable:						
Hydraulic Winkie..	NAp	300[3] (1000)[3]	240[4] (800)[4]	44-30[5] (100)[5]	NAp	550 (250)
Diameck 251.......	NAp	370 (1200)	NAp	NAp	NAp	2500 (1100)
Acker Mark III....	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	NAp	2600 (1200)
Acker Mark II.....	NAp	550 (1800)	495 (1625)	380 (1250)	340 (1100)	2860 (1300)
Ingersol Rand T4W.	NAp	NAp	NAp	NAp	760[2] (2500)[2]	

NAp Not applicable.

[1] Q Series wire line.

[2] Rated capacity.

[3] IEX.

[4] IAX.

[5] BW.

NOTE: Figures are maximum capacities under ideal conditions.

Source: Data from William G. Salisbury, Salisbury & Dietz Inc., as collected from literature and as provided by contractors, May 1980.

DRILLING

CORE DRILLING

Core drilling varies from nonexistent to extensive, depending on many unknown factors. Core drilling is performed on centers varying from 30- to 245 m and to varying depths. The following tabulation gives the average range of costs for core dia- meter and depth of hole for drilling medium hard rocks. Costs could be higher or lower depending on hardness, location, access, and weather conditions.

Drilling cost, dollars per meter

Core		Drilling depth range, m			
Size	Diam, cm	0-150	150-300	300-450	450-600
PQ.......	8.49	\$100-\$115	\$125-\$138	NAp	NAp
NC[1]......	6.10	62- 79	69- 85	\$90	\$100
NX[1]......	5.40	59- 71	62- 75	80	90
BX.......	4.13	49- 64	52- 69	75	85
AX.......	2.86	43- 57	49- 62	70	80
EX.......	2.22	36- 52	43- 59	NAp	NAp

NAp Not applicable.

[1] Primarily surface exploration core sizes.

Subcontractor Factor If drilling is accomplished by a drilling subcontractor, multiply cost by 1.10 to compensate for subcontractor's markup.

ROTARY DRILLING

Conventional..................	\$125-\$185/h; \$7-\$36/m.
Reverse circulation...........	\$125-\$185/h; \$11-\$39/m.
Mobilization-demobilization...	\$1,500-\$2,500 and \$1.90-\$2.20/km.

PERCUSSION DRILLING

Downhole hammer...............	\$40-\$59/m.
Mobilization-demobilization...	\$1,500-\$2,500 and \$1.90-\$2.20/km.

CAUTION: Drilling costs are impacted significantly by demand. Costs correlate poorly with industrial inflation factors. Base costs here are representative of January 1984 costs, a time of low drilling demand and very depressed prices for drilling contractors.

Contract downhole logging costs--survey changes

	Cost per--			Plus cost
	Day	Week	Month	per meter
Portable gamma ray rental	NAp	NAp	[1]$2,600	NAp
Truck gamma ray surface profile resistivity:				
Daily	$420	NAp	NAp	$0.69
Weekly	NAp	$1,588	NAp	0.36
Monthly	NAp	NAp	4,646	0.36
Directional survey	NAp	NAp	735	0.15

[1] Month minimum.

Loss of equipment charge--Contractee is charged for replacement value of equipment lost. Probes may cost $3,200 and cable may cost $2.30/m.

Mobilization-demobilization charge - $50/d/person; $0.90/mile over 100 mile/d mobilization.

GAS--MILEAGE:

Assume on average, 80 mi/d for 18 days going to field project.
Total miles = 1,440 miles.
Assume 300 miles are driven each way going to and from project.
Total miles = 600 miles.

1,440 miles + 600 miles = 2,040 miles
(2,040)($0.10/mi) = $204/month

Assume: 20 working d/month, 10 days off/month (8 days rest and 2 days off, holiday, weather, project supervisor discussions).

LABOR:

	Annual salary equivalent (overhead)	Sampling program work schedule
Supervisor	$36,000 (35%)	4 d/month (includes travel, supervisory, and interpretation.)
Full-time geologist	26,000 (35%)	Full-time (20 d/month).
Part-time sampler	18,000 (15%)	Full-time (20 d/month).

	Annual cost plus salary overhead	Per month	$/sampling project month
1 supervisor	$48,600	$4,050	$ 810
1 full-time geologist	35,100	2,925	2,925
1 part-time sampler	20,700	1,725	1,725
Pay total for month			$5,460

TRAVEL:

A. Per diem:	Per diem rate	Days on per diem	Total per diem
Supervisor..........	$50	2.75	$ 137.50
Full-time geologist.	50	19.0	950.00
Part-time sampler...	50	19.0	950.00
			2,037.50
Per diem total for month.			2,038.00

B. Vehicle Cost:

Assume on average 300 miles to project area and 80 miles driven to and from point of lodging.

1. Geologist and Sampler

Vehicle is 4 x 4 Ford Bronco, lease rate is $1,200 month, mileage free. Assume vehicle uses unleaded gas costing $1.10/gal at a rate averaging 12 mi/gal.

$1.10/12 = 9.2¢/mi + 0.8¢/mi oil and lube = 10¢/mi

a. Gas cost
   1. Miles to and from project area:
      300 mi/trip x 2 trips/work period x 2 trips/month
      = 1,200 mi/month.

   2. Miles to and from field lodging to project:
      17 one-way trips x 40 miles x 2 work periods
      = 1,360 mi/month.

   Total cost = (1,200 miles + 1,360 miles)(10¢/mi) =
   $256/month.

b. Four-wheel drive rental-lease - $1,200/month, unlimited mileage, Ford Bronco.

2. Supervisor

Assume supervisor makes one trip per month to project area. Day of travel each way.

Assume vehicle cost of supervisor is 25¢/mi.

Monthly gas cost: 300 miles x 2 (one-way trips from main office)
600
40 miles x 2 (motel to project) = 80
680 miles

680 miles x 25¢/mi = $170/month.

3. Total Monthly Transportation Cost

1. 4 x 4 vehicle gas cost.........	$256
2. 4 x 4 vehicle lease cost.......	1,200
3. Supervisor vehicle-gas cost....	170
	1,626

SAMPLING SCHEDULE:

20 d/month work schedule

3	d/month travel (1.5 days spent on travel each 10-day work period)
2	d/month laying out "zero" base lines
0.5	d/month sample handling
5.5	days of nonsampling

20 days less 5.5 days of nonsampling = 14.5 days of sampling per month.

Sample rate (from Amselco, Inc., Montana)

1. 30^o to 40^o slope, average open conditions, 100-ft spacing, 2 persons with Brunton and tape working from previously from Amselco, surveyed base line. Equals 65 samples/d.

   Total samples/month = 65 samples/d x 14.5 days = 942.5 samples/month.

2. Flat and few obstructions, 100-ft sample intervals, esti- mated 100 samples/8-h day.

   Total samples/month = 100 samples/d x 14.5 days = 1,450 samples/d.

3. Thick underbrush, e.g., blackberries, vine maple, possible swamp.

   - add extra 2 d/month for base line.
   - estimate 25 to 50 samples/d, based on sampling interval (100-, 50-, 25-ft).
   - will use 38 samples/d.

   (38 samples/d)(14.5 days - 2 days) = 475 samples/month.

MISCELLANEOUS FIELD EQUIPMENT COSTS:

Sample Cost:
Assume 70¢/sample. Includes sample bag, label, area map, flagging-marking, and postage. Others would include field clothing and equipment.

Sample Preparation and Drying Prior to Assay (from Amselco, going rate):

Preparation..	$0.80
Drying.......	0.25
Total......	1.05

Total Sample Cost for Miscellaneous Field Equipment and Sample Preparation:

$0.70
1.05
1.75

COST SUMMARY:

Labor (monthly)

Salary..........	$5,386
Per diem........	2,038
Transportation...	1,626
Total.........	9,050

Initial sampling costs

Condition	Cost per sample[1]	Field equipment and sample preparation	Total cost per sample
Good, 1,450 samples per month.........	$6.24	$1.75	$8.00
Average, 943 samples per month........	9.59	1.75	11.34
Poor, 475 samples per month...........	19.05	1.75	20.80

[1] Based on a $9,050 labor cost per month.

The above costs assume a relatively large long-term sampling program as opposed to a short 1-, 2-, 3-, or so, day sampling program. Per sample cost for the latter case could be substantially larger.

The initial sampling costs were provided to an exploration contractor who is accustomed to doing this type of work. The contractor felt the initial sampling costs were low by $2.00 to $3.00 across the board. The explanation may be that additional in-office expenses are incurred such as planning, programming, plotting, map drafting, analytic plotting, etc.

As a result, the initial per sample costs are increased to $2.50 and the totals are rounded to the nearest higher dollar.

Sampling costs

Condition	Sample rate	Field equipment and sample preparation	Total cost per sample1
Good, 1,450 samples per month.........	**$7.99**	**$2.50**	**$11.00**
Average, 943 samples per month........	**11.34**	**2.50**	**14.00**
Poor, 475 samples per month...........	**20.80**	**2.50**	**24.00**

[1] Rounded.

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.1. CLEARING

The curve for clearing during preproduction development is based on estimated costs for medium-light growth on terrain with a side slope of 20% to 50%, one shift per day. Estimate one tree, 0.33 m in diameter, per 40 square m^2.

The total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a clearing area (X), in total hectares. The curves are valid for operations between 1 and 1,000 ha (from 500 to 1,000 ha, the costs are expected to remain constant). The curves include all daily operating and maintenance costs associated with clearing a land surface for further development.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2{,}171.220(X)^{-0.120}$
The operating labor costs are distributed as follows:

Direct labor...............	84%
Maintenance labor..........	16%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator............	21%	$16.33
Truck driver..............	6%	15.89
General laborer...........	73%	13.66

The average wage for labor is $14.28 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 269.796(X)^{-0.0303}$
For clearing operations from 1 to 500 ha, the supply cost consists of 78% fuel oil (for burning wood and scrub) and 22% tools, cables, and chokers. For clearing operations of 500 to 1,000 ha, the supply cost consists of 83% fuel oil and 17% tools, cables, and chokers.

(E) Equipment Operating Cost $(Y_E) = 667.618(X)^{-0.0672}$
The general equipment cost component distribution is

	Repair parts	Fuel and lube	Tires
Crawler dozers.............	51%	49%	-
Trucks, pickups, and chainsaws.............	14%	80%	6%

The equipment operating cost consists of 87% for crawler dozers and 13% for trucks, pickups, and chainsaws.

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factors:

Brush factor $(Y_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(Y_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 50%, multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(Y_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(Y_{S\ 50\%-100\%}) = 1.2$

For clearing on terrain with side slopes greater than 100%,

Side slope factor $(Y_{S\ +100\%}) = 2.5$

Burning Factor When the burning of cleared brush and trees is prohibited because of environmental regulations, the brush and trees will have to be stacked or buried. If burning is prohibited, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.2$

Supply factor $(F_S) = 0.2$

Equipment operation factor $(F_E) = 1.2$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

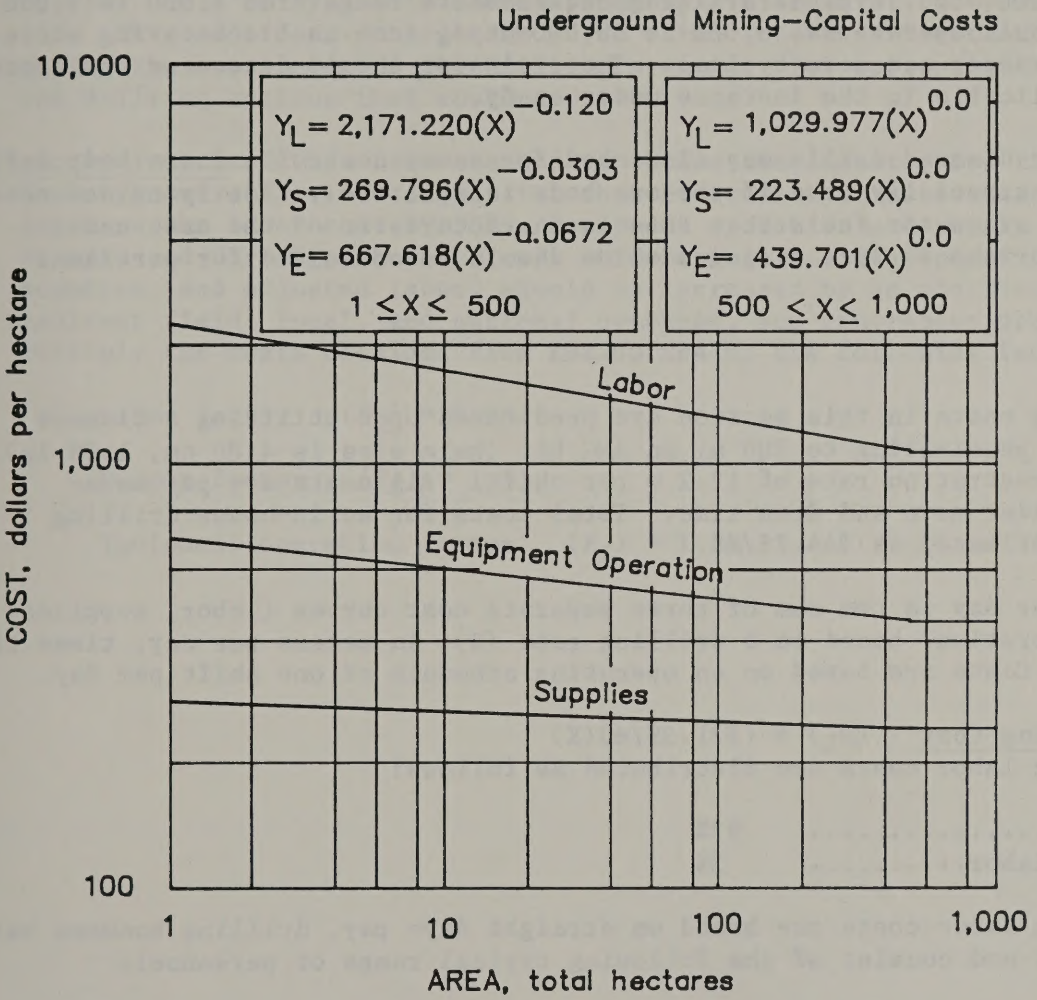
Shifts per day.............	1	2	3
Factor.....................	1.75	1.56	1.50

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup.

Labor factor $(F_L) = 1.50$

Supply factor $(F_S) = 1.20$

Equipment operation factor $(F_E) = 1.20$



4.2.1.1. Clearing

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.2. CORE DRILLING

Core drilling requirements vary considerably from mine to mine. For steeply dipping veins that require continuing development, as mining progresses down- ward, the amount drilled is relatively high; for near surface, flat-lying ore bodies for which grade and ore extent are easily determined, drilling require- ments will be minimal following initial exploration and development. For small to medium sized vein mines, 500 to 2,000 mtpd, typical drilling requirements range from 1,000 to 5,000 m/yr; for large bulk operations, 5,000 to 50,000 mtpd, such as block caving mines, 5,000 m/yr and greater are more typical. The evaluator should determine the approximate value appplicable in the instance under study.

Surface rotary or diamond drills may also used for assay control and ore body definition. This is especially true if the ore body is relatively flat lying and near surface. If the evaluator feels that this is characteristic of the case under study, the appropriate surface mining section should be consulted for pertinent costs.

BASE CURVES

The core drilling costs in this section are predicated upon utilizing a diamond drill capable of penetrating to 300 m, an AWG bit (hole size is 4.80 cm, 1.89 in), and an average penetration rate of 12.2 m per shift. All costs are per meter drilled and consider move and down time. Total costs for an in-house drilling program can be estimated as $44.75/m.

The total cost per day is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a drilling rate (X), in meters per day, times the cost per meter. Costs are based on an operating schedule of one shift per day.

(L) Labor Operating Cost $(Y_L) = (\$21.38/m)(X)$
The operating labor costs are distributed as follows:

Direct labor...............	97%
Maintenance labor..........	3%

The operating labor costs are based on straight days pay, drilling bonuses have been ignored, and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Drillers...................	50%	$18.11
Drillers helper............	50%	13.66

Average wage for labor is $15.89 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = (\$20.67/m)(X)$
The supply cost consists of 70% drill bits, drill rods, and core barrel assembly parts, 7% electric power, and 23% miscellaneous items.

(E) Equipment Operating Cost $(Y_E) = (\$2.70/m)(X)$
The equipment operating cost consists of 48% for parts, 13% for lubrication, and 39% for miscellaneous costs for drill and pump equipment.

ADJUSTMENT FACTORS

Cut/out Costs In many instances it is necessary to blast cut/outs for a drilling stations to ensure that the drilling crew does not impede traffic along the drifts. This is typically accomplished by a minimum of two rounds in either rib. This additional charge should be taken into consideration when determining the total cost of the drilling program. For appropriate costs refer to the drifting section that would apply.

Contractor Factor It has become standard within the industry for the drilling to be done by contractor. To adjust for this eventuality, the evaluator should increase the labor cost by 38%. Equipment operation and supply costs will not be affected directly, however; all three categories (equipment operation, supplies, and adjusted labor) should be increased by an additional 35% for indirect field, local, and national overhead, and contractor profit charges. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.86$

Supply factor $(F_S) = 1.35$

Equipment operation factor $(F_E) = 1.35$

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.3. SINKING SHAFTS

The total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 40 m^2, with average advances of 1.9 m/d in the smaller shafts and 1.3 m/d overall in the larger shafts, operating three shifts per day. The curves are based on circular shafts with concrete lining. The total cost per meter is multiplied by the total meters of excavation needed during development to obtain the capital cost.

Services installed in the shaft include guides, manways, and air, water, vent, and signal lines. Sinking is considered to be done with a sinking headframe. Costs for permanent hoisting facilities are included in section 4.2.3.1. (Hoisting Facilities).

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 615.595(X)^{0.542}$

The operating labor costs are distributed as follows:

Direct labor...............	84%
Maintenance Labor..........	16%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners.....................	34%	$18.44
Helpers....................	22%	15.09
Support....................	44%	17.04

Average wage for labor is $16.35 per worker-hour (including burden and average shift differential)

(S) Supply Operating Cost $(Y_S) = 182.051(X)^{0.558}$

The supply cost consists of 21% explosives, 34% steel items, 38% miscellaneous items, 6% electricity, and 1% timber. Supplies include drill bits and steel, powder, caps, timber, hanging rods, vent line, compressed air pipe, pump line, water line, concrete line, blasting lines, and bell cord.

(E) Equipment Operating Cost $(Y_E) = 681.476(X)^{0.407}$

The equipment operating cost consist of 88% for repair parts, 7% for fuel and lubrication, and 5% for tires (tires used on topside crane and loader servicing the shaft sinking). The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for drills, fans, muckers, and other equipment used to sink the shaft.

ADJUSTMENT FACTORS

Rock Hardness Factor Shaft sinking productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

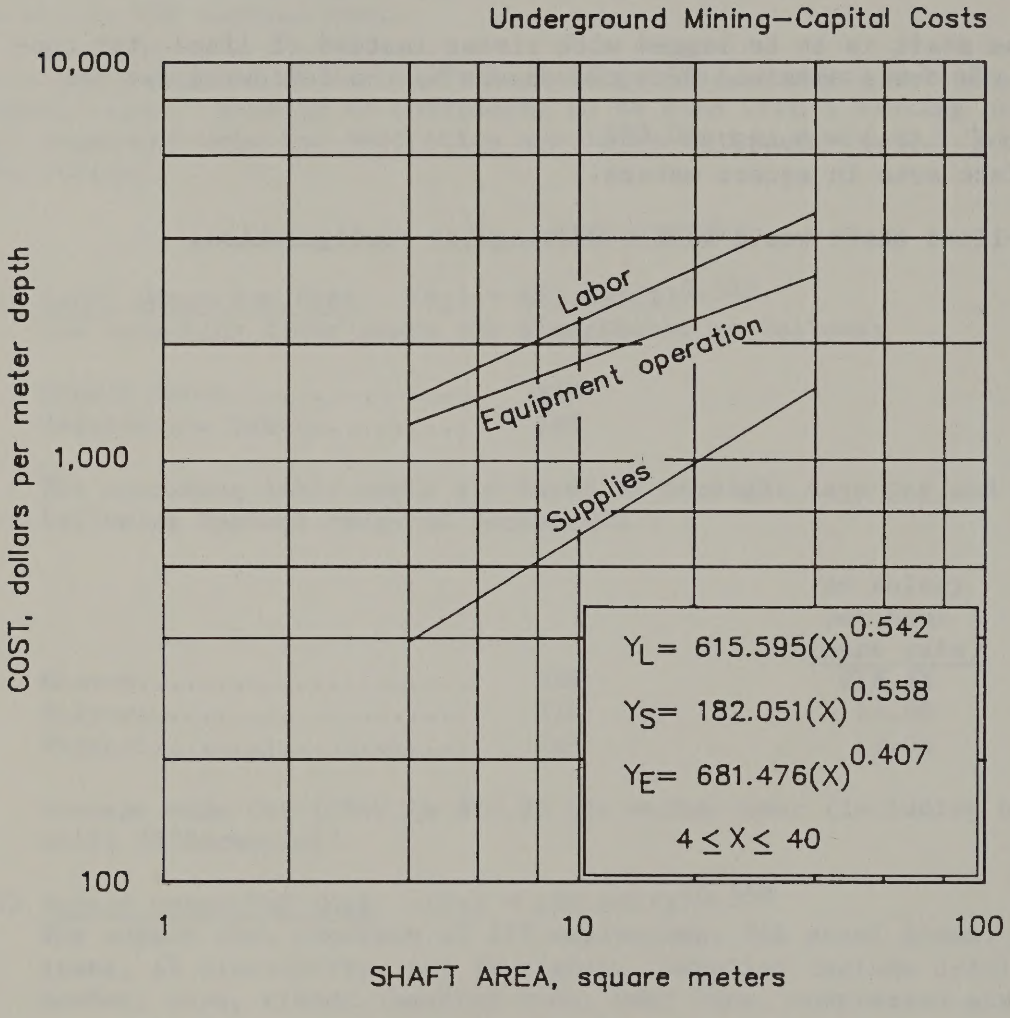
Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Timber Factor If the shaft is to be lagged with timber instead of lined with concrete, multiply the costs obtained from the curves by the following factor:

Timber factor $(F_T) = 0.482(X)^{0.077}$
where X = face area in square meters.

Assume a timber-lined shaft would have a rectangular configuration.



4.2.1.3. Sinking shafts

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.1. DRIFT DEVELOPMENT
SMALL DRIFTS FOR RAIL HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 2 to 3 m/d, with productivity averaging 0.39 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with 3-in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, track laying, lunch, and travel. Muck is loaded into 2- or 3-yd^3 development cars using an overshot mucker. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 3 and 12 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of drift needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 79.926(X)^{0.764}$

The operating labor costs are distributed as follows:

Direct labor...............	95%
Maintenance labor..........	5%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (3 to 6 m^2)	Large (6 to 12 m^2)	Av salary per hour (base rate)
Miners.....................	90%	83%	$18.31
Helpers....................	-	11%	13.86
Motor operators............	10%	6%	16.09

Average wage for labor is $17.56 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 73.283(X)^{0.602}$

The supply cost consists of 44% steel items, 23% explosives, 10% drill bits and steel, 10% ventilation materials, 5% material waste, 4% timber, 3% ballast, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rock bolts, water pipe, compressed air pipe, electricity, steel rail, ties, ballast, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 4.869(X)^{0.647}$
The equipment operating cost consists of 73% for maintenance and overhaul parts, 11% for fuel, 8% for ground engaging components, and 8% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and ground engaging components. Equipment used in drifting includes jacklegs, overshot muckers, ore cars, jackhammers, locomotives, and auxiliary fans.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.10$

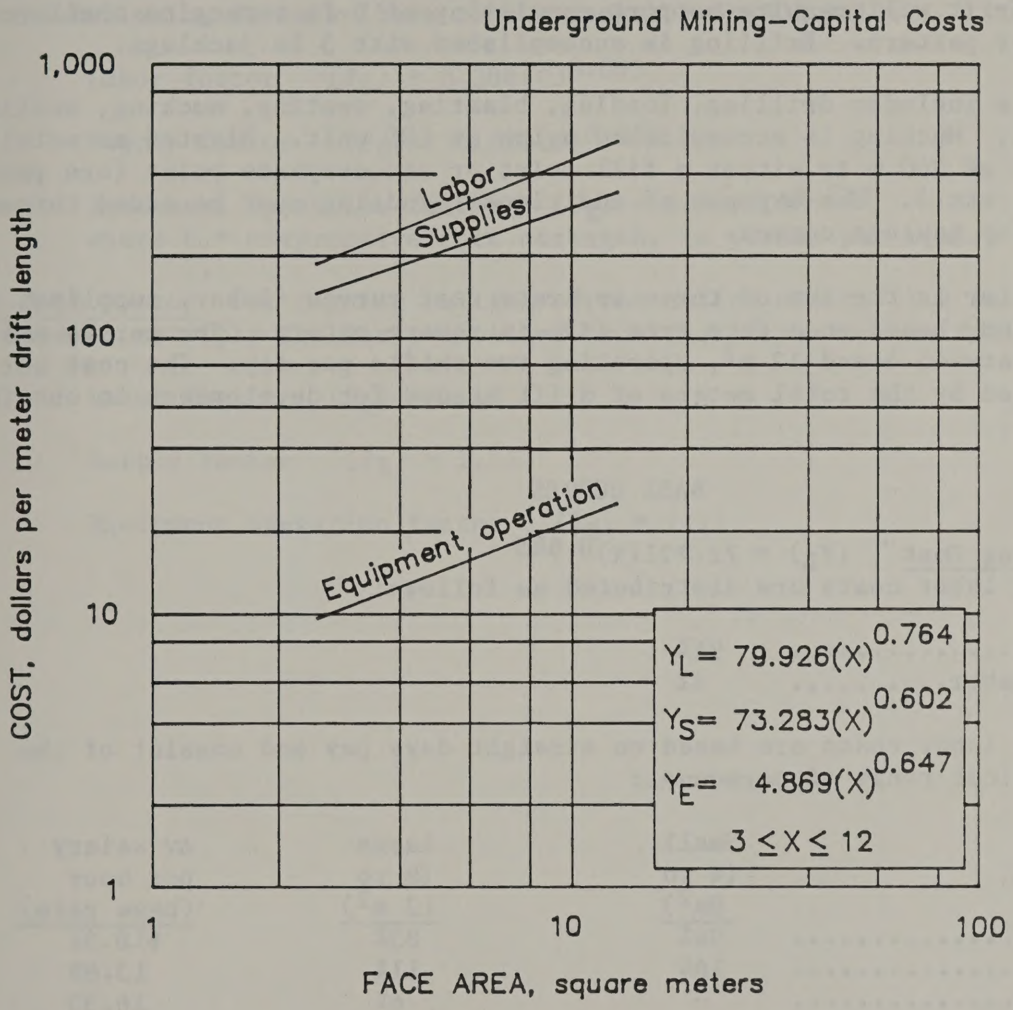
Equipment operation factor $(F_E) = 1.16$

Timbering Factor If the drifts require timbering, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.30$

Supply factor $(F_S) = 1.39$

These factors will account for standard cap-and-post timbering plus lagging for the entire length of the drift.



4.2.1.4.1. Drift development
SMALL DRIFTS FOR RAIL HAULAGE

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.2. DRIFT DEVELOPMENT
SMALL DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 2.4 to 3.6 m/d, with productivity averaging 0.49 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with 3 in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using an LHD unit. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 12 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of drift needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 72.721(X)^{0.685}$
The operating labor costs are distributed as follows:

Direct labor...............	96%
Maintenance labor..........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (4 to $8m^2$)	Large (8 to 12 m^2)	Av salary per hour (base rate)
Miners.....................	84%	83%	$18.31
Helpers....................	16%	11%	13.86
LHD Operators..............	-	6%	16.53

Average wage for labor is $17.30 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 43.313(X)^{0.687}$
The supply cost consists of 33% steel items, 33% explosives, 15% ventilation materials, 13% drill bits and steel, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rock bolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 1.360(X)^{1.188}$
The equipment operating cost consists of 64% for maintenance and overhaul parts, 18% for tires, 13% for fuel, and 5% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jacklegs, LHD's, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

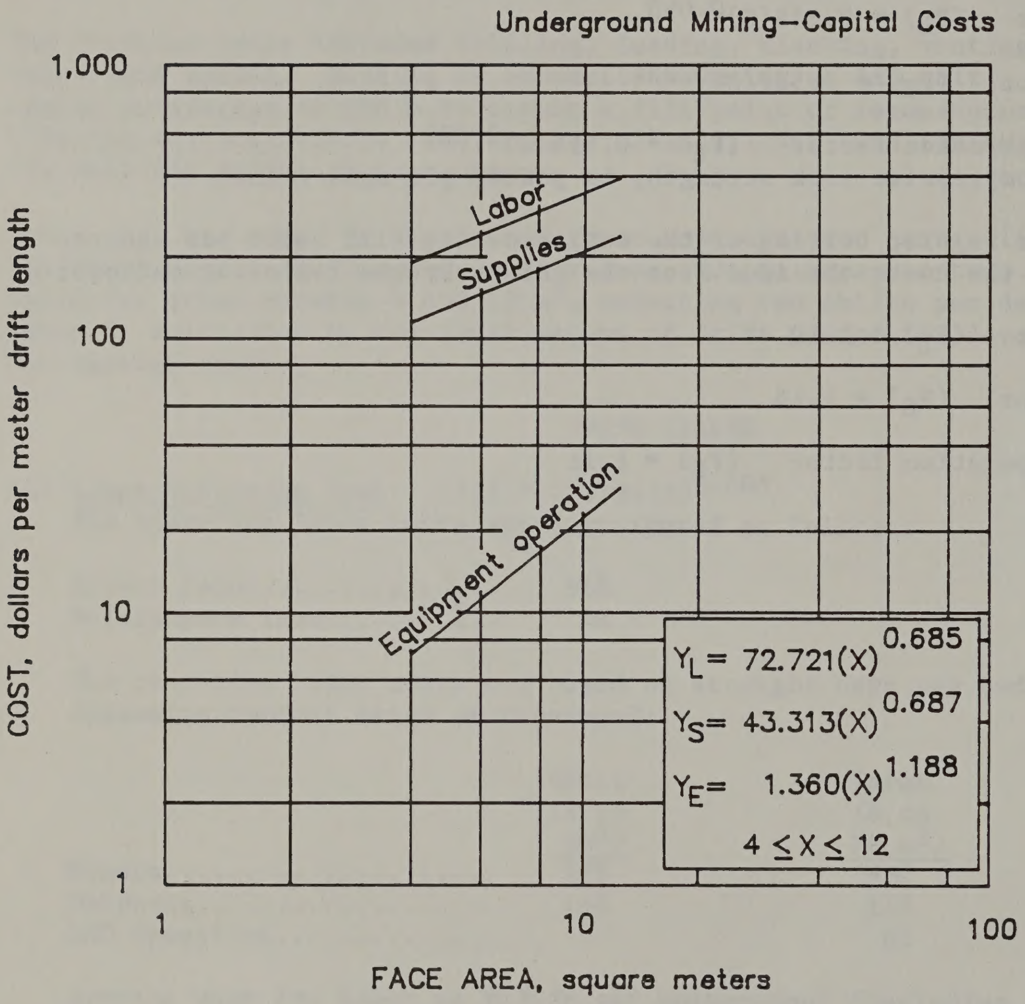
Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.10$

Supply factor $(F_S) = 1.15$

Equipment operation factor $(F_E) = 1.11$



4.2.1.4.2. Drift development
SMALL DRIFTS FOR RUBBER-TIRED HAULAGE

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.3. DRIFT DEVELOPMENT
MEDIUM DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 5.4 to 6.0 m/d, with productivity averaging 0.71 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with two- or three-boom jumbos.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using an LHD unit. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 6 and 20 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of drift needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 86.960(X)^{0.349}$
The operating labor costs are distributed as follows:

Direct labor...............	93%
Maintenance labor..........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (6 to 13 m^2)	Large (13 to 20 m^2)	Av salary per hour (base rate)
Miners.....................	69%	67%	$18.31
Helpers....................	21%	20%	13.86
LHD operators..............	10%	7%	16.53
Utility workers............	-	6%	16.98

The average wage for labor is $17.21 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 27.390(X)^{0.855}$
The supply cost consists of 53% steel items, 29% explosives, 12% ventilation materials, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rock bolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 4.497(X)^{0.684}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 24% for tires, 14% for fuel, and 5% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jumbo mounted drifters, LHD's, jacklegs, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.14$

Equipment operation factor $(F_E) = 1.42$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.03$

Supply factor $(F_S) = 1.24$

Equipment operation factor $(F_E) = 1.15$

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.64$

Supply factor $(F_S) = 1.72$

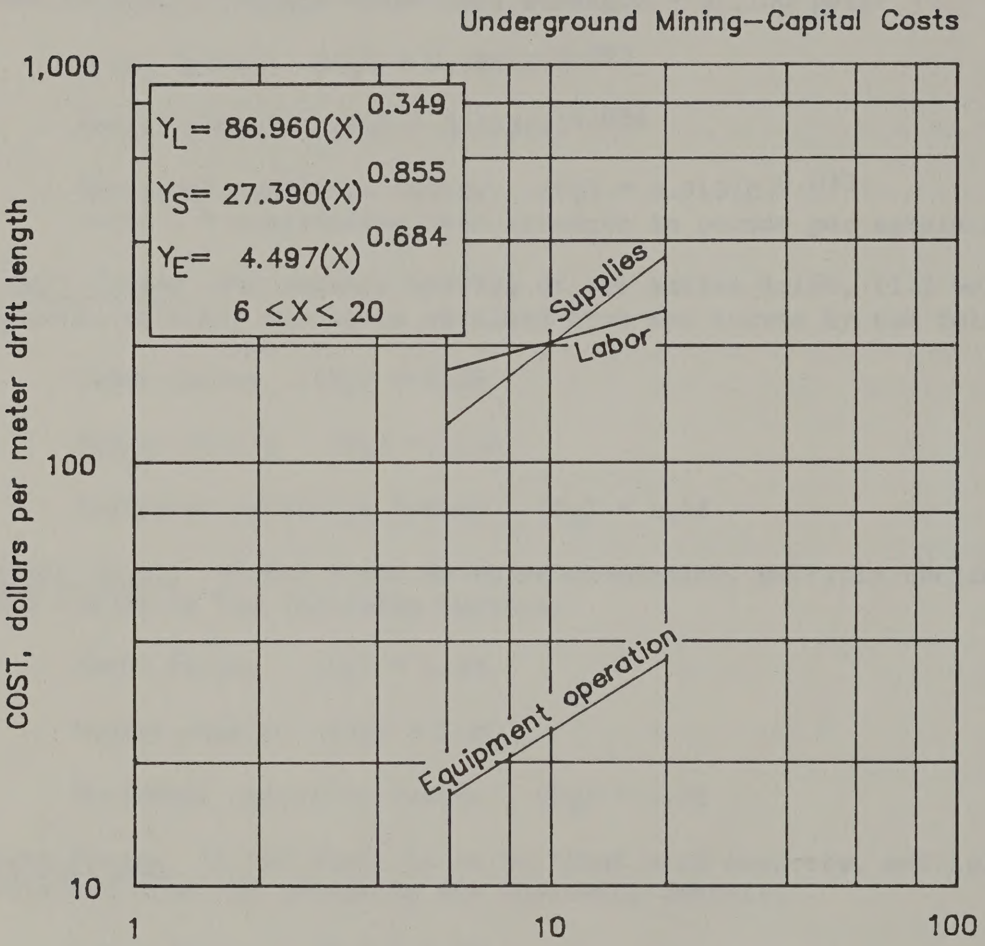
Equipment operation factor $(F_E) = 2.26$

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.37$

Supply factor $(F_S) = 2.47$

Equipment operation factor $(F_E) = 1.19$



4.2.1.4.3. Drift development
MEDIUM DRIFTS FOR RUBBER—TIRED HAULAGE

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.4. DRIFT DEVELOPMENT
LARGE DRIFTS FOR RAIL HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 5.0 to 6.8 m/d, with productivity averaging 0.57 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with 3 in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, track laying, lunch, and travel. Muck is loaded into 6-to 10-yd^3 development cars using an overshot mucker. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 8 and 25 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of drift needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 27.037(X)^{0.857}$
The operating labor costs are distributed as follows:

Direct labor...............	90%
Maintenance labor..........	10%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (8 to 16 m^2)	Large (16 to 25 m^2)	Av salary per hour (base rate)
Miners.....................	73%	68%	$18.31
Helpers....................	12%	17%	13.86
Utility workers............	8%	-	16.98
Track workers..............	-	9%	16.53
Motor operators............	7%	6%	16.09

The average wage for labor is $17.34 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 63.689(X)^{0.693}$
The supply cost consists of 53% steel items, 19% explosives, 10% drill bits and steel, 8% ventilation materials, 5% material waste, 3% timber, 1% ballast, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord,

rock bolts, water pipe, compressed air pipe, electricity, steel rail, ties, ballast, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 1.437(X)^{1.056}$
The equipment operating cost consists of 83% for maintenance and overhaul parts, 9% for ground engaging components, 4% for fuel, and 4% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and ground engaging components. Equipment used in drifting includes jumbos, overshot muckers, ore cars, jacklegs, jackhammers, locomotives, scissor lifts, rail tampers, roof bolters, and auxiliary fans.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.02$

Supply factor $(F_S) = 1.09$

Equipment operation factor $(F_E) = 1.23$

Dual Track Factor To account for two sets of tracks in the drift, multiply the costs obtained from the curves by the following factors: (drifts greater than 16 m^2):

Labor factor $(F_L) = 1.11$

Supply factor $(F_S) = 1.26$

Equipment operation factor $(F_E) = 1.17$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.02$

Supply factor $(F_S) = 1.16$

Equipment operation factor $(F_E) = 1.15$

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.52

Supply factor (F_S) = 1.81

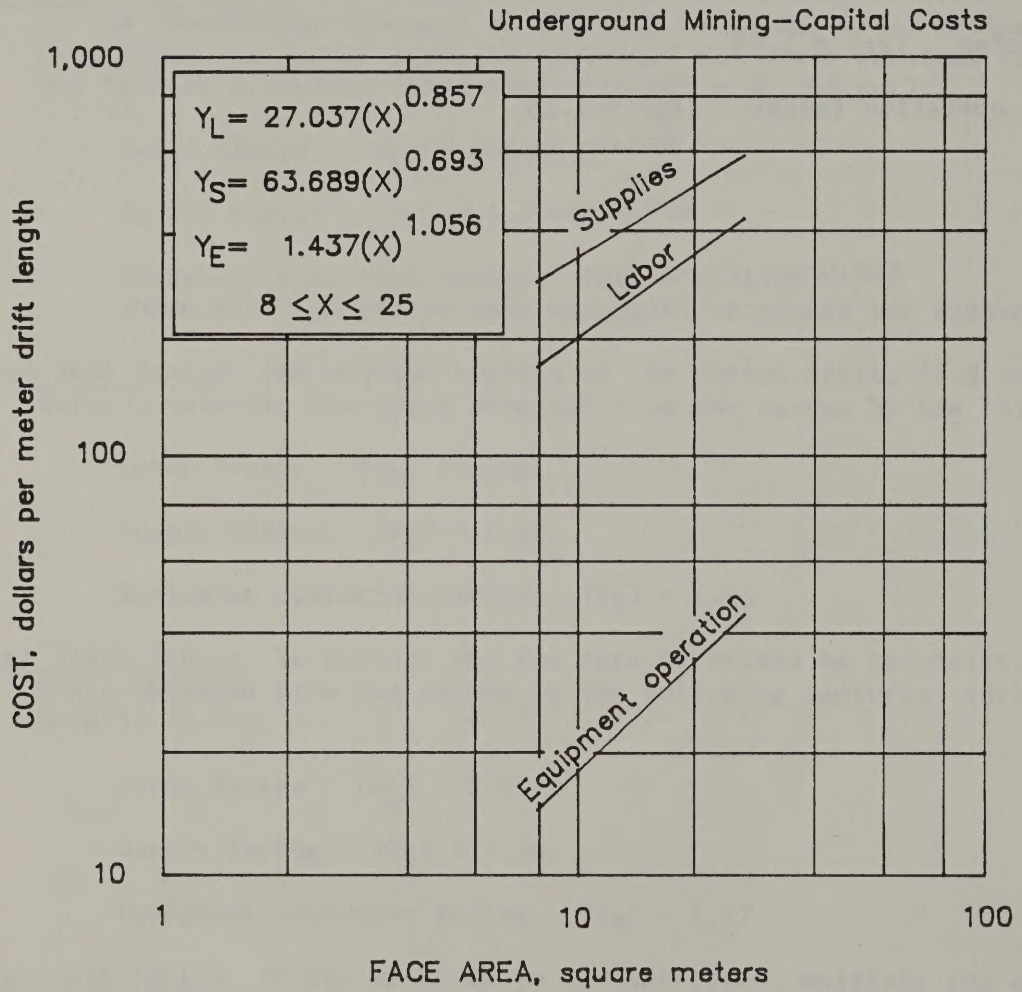
Equipment operation factor (F_E) = 2.14

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.29

Supply factor (F_S) = 1.95

Equipment operation factor (F_E) = 1.10



4.2.1.4.4. Drift Development
LARGE DRIFTS FOR RAIL HAULAGE

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.5. DRIFT DEVELOPMENT
LARGE DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 4.6 to 5.4 m/d, with productivity averaging 0.55 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with two- or three-boom jumbos.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using front-end loaders and trucks. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 20 and 50 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of drift needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 43.360(X)^{0.542}$
The operating labor costs are distributed as follows:

Direct labor...............	91%
Maintenance labor..........	9%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (20 to 50 m^2)	Large (35 to 50 m^2)	Av salary per hour (base rate)
Miners.....................	68%	59%	$18.31
Helpers....................	11%	20%	13.86
Loader operators...........	7%	6%	16.53
Utility workers............	14%	15%	16.98

The average wage for labor is $17.28 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 57.018(X)^{0.617}$
The supply cost consists of 34% explosives, 33% steel items, 15% drill bits and steel, 12% ventilation materials, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rock bolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 4.144(X)^{0.661}$
The equipment operating cost consists of 60% for maintenance and overhaul parts, 25% for fuel, 11% for tires, and 4% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jumbo mounted drifters, front end loaders, jacklegs, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.12$

Supply factor $(F_S) = 1.13$

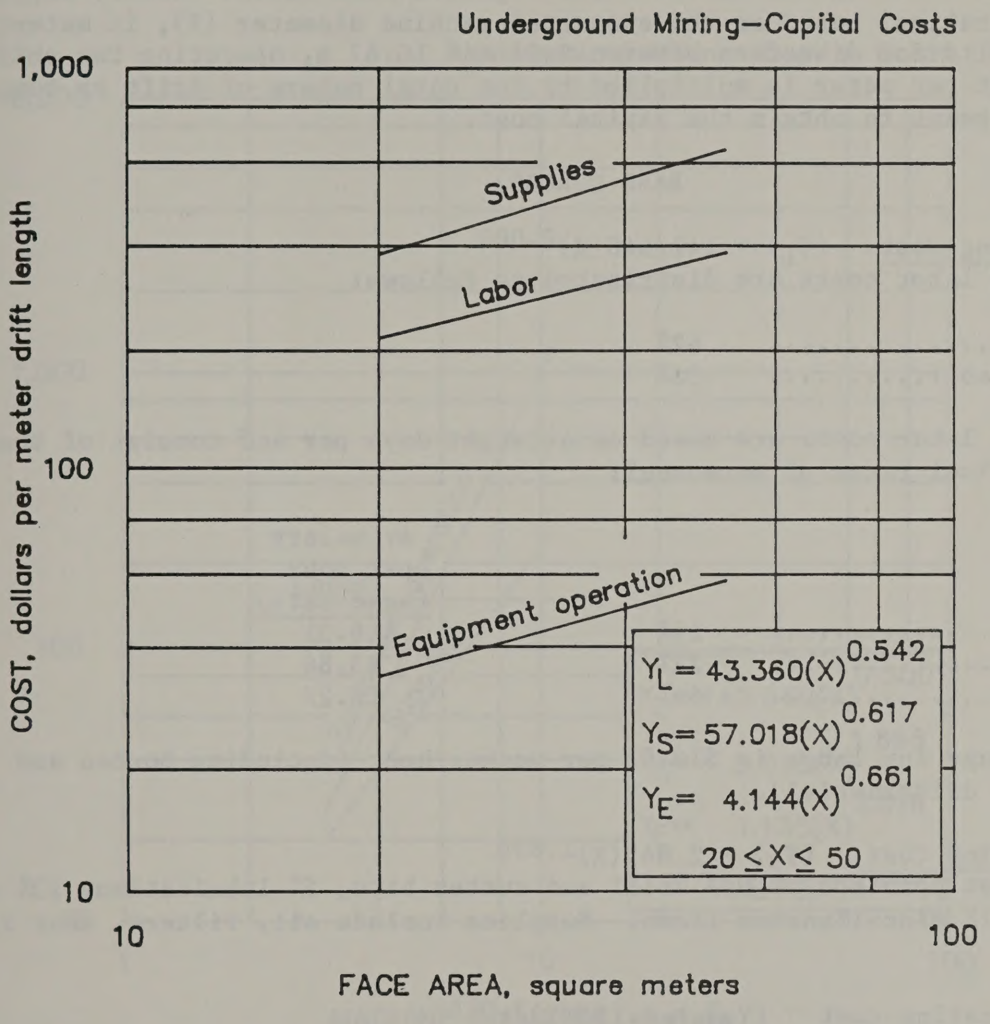
Equipment operation factor $(F_E) = 1.31$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.03$

Supply factor $(F_S) = 1.19$

Equipment operation factor $(F_E) = 1.15$



4.2.1.4.5. Drift development
LARGE DRIFTS FOR RUBBER—TIRED HAULAGE

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.4.6. DRIFT DEVELOPMENT
DRIFT-TUNNEL BORING

This section covers costs associated with a mine using drift-tunnel boring machines (TBM's) and associated equipment.

The total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the excavated machine diameter (X), in meters. The curves are valid for diameters between 2.74 and 10.67 m, operating two shifts per day. The cost per meter is multiplied by the total meters of drift or tunnel needed for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 142.640(X)^{0.000}$

The operating labor costs are distributed as follows:

Direct labor...............	62%
Maintenance labor..........	38%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Operator...................	14%	$18.31
Helpers....................	22%	13.86
Support....................	64%	16.27

The average wage for labor is $15.92 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.845(X)^{1.896}$

The supply cost consists of 81% drill and cutter bits, 5% lubrication, 13% electricity, and 1% miscellaneous items. Supplies include oil, filters, wear items, and power.

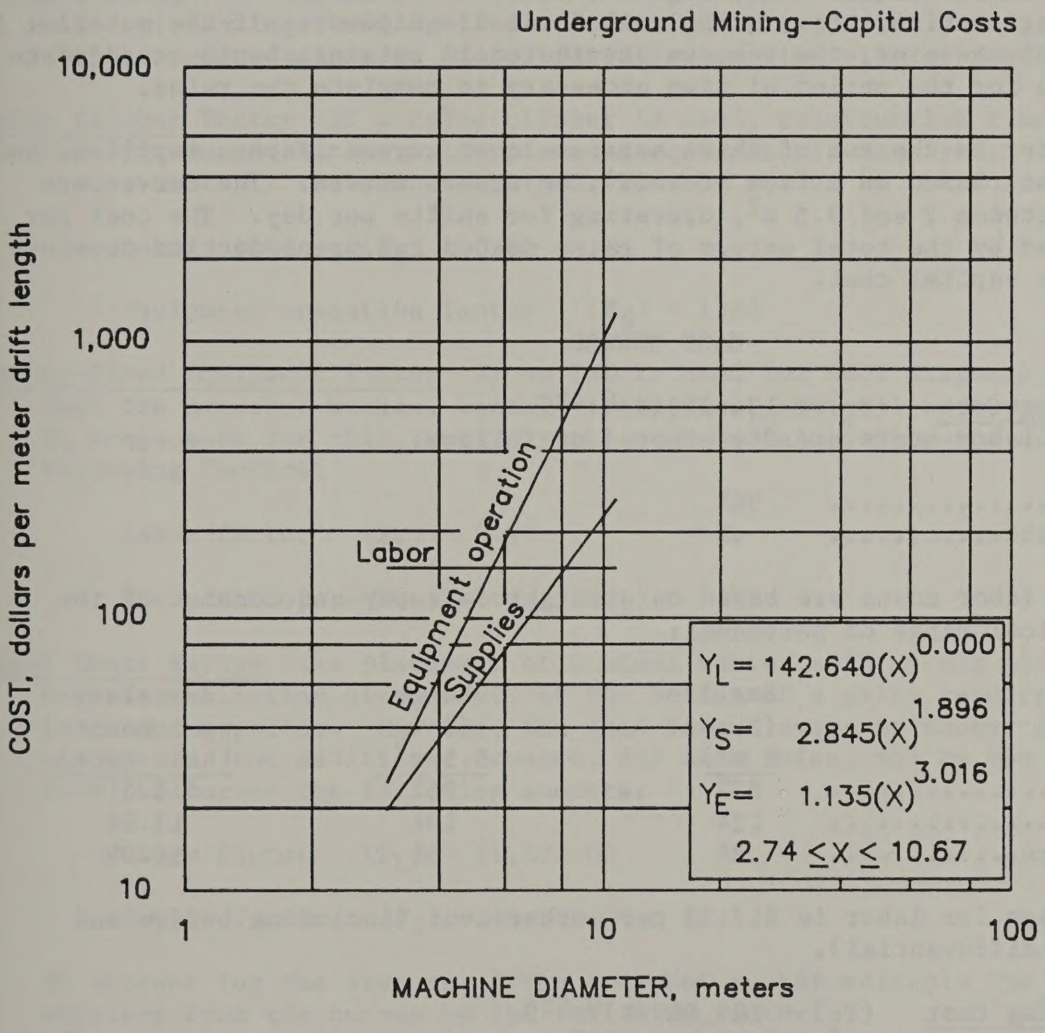
(E) Equipment Operating Cost $(Y_E) = 1.135(X)^{3.016}$

The equipment operating cost consists of 69% for maintenance and overhaul parts and 31% for cutter costs. The equipment operating curve covers daily maintenance and repair, repair parts, and cutter costs.

ADJUSTMENT FACTOR

Contractor Factor A contractor is often used with drift-tunnel boring because of the specialized nature of the machinery. If a contractor is used, multiply the costs obtained from the curves by the following factor:

Labor factor $(F_L) = 1.94$



4.2.1.4.6. Drift development
DRIFT/TUNNEL BORING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.5.1. RAISE DEVELOPMENT
DRIVING RAISES

The costs calculated from these curves represent two-compartment, conventionally driven raises. It is assumed that the raises are timbered and lagged, and contain water and compressed air lines. Advance rates range from 0.83 m per worker-shift for a 2.3 m^2 raise to 0.49 m per worker-shift for a 9.3 m^2 raise. It is assumed that blasted material is hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rail mounted equipment. If the material is to be hauled out of the mine, the tonnage attributed to raising should be added to the haulage curves for the period of time necessary to complete the raise.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 2 and 9.5 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of raise needed for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 134.819(X)^{0.438}$
The operating labor costs are distributed as follows:

Direct labor..............	96%
Maintenance labor.........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (2 to 6 m^2)	Large (6 to 9.5 m^2)	Av salary per hour (base rate)
Miners.....................	85%	76%	$18.31
Helpers....................	12%	19%	13.86
Motor operators...........	3%	5%	16.09

The average wage for labor is $17.53 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 109.009(X)^{0.526}$
The supply cost consists of 51% timber, 19% explosives, 10% steel pipe, 10% ventilation materials, 4% material waste, 5% drill bits and steel, and 1% electricity. Supplies include drill bits and steel, powder, caps, lead wire, water pipe, compressed air pipe, vent duct, electricity, and timber.

(E) Equipment Operating Cost $(Y_E) = 2.267(X)^{0.757}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 33% for ground engaging components, and 10% for lubrication. The equipment curve covers maintenance and overhaul parts, ground engaging components, and

lubrication. Equipment used for raising includes stoper drills, fans, locomotives, ore cars, and overshot muckers.

ADJUSTMENT FACTORS

Timber Factor If the raise is not timbered and lagged, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.76$

Supply factor $(F_S) = 0.50$

These factors will account for the fact that the only timber needed will be for ladders, landings, and drill platforms (stull supported), and that the labor will be reduced since no timber installation time will be required.

Raise Climber Factor If a raise climber is used, construction time is significantly reduced, but an extra piece of equipment is required. To modify the costs, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.56$

Equipment operation factor $(F_E) = 1.44$

Rubber-Tired Equipment Factor If an LHD is used for muck disposal, it is assumed that the overshot mucker, battery locomotive, and rail cars would be eliminated. To compensate for this, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.99$

Equipment operation factor $(F_E) = 1.25$

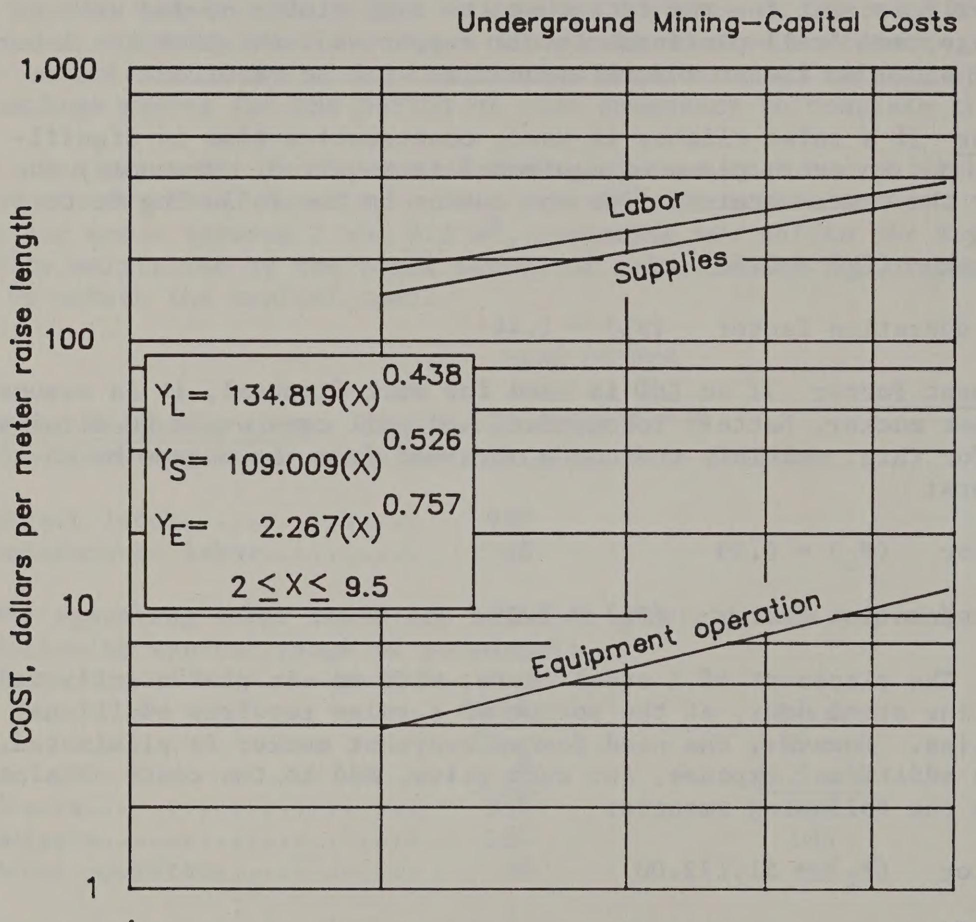
Steel Chute Factor The placement of a steel chute, with an air piston activated, reverse guillotine steel door, at the bottom of a raise requires additional labor and supplies. However, the need for an overshot mucker is eliminated. To account for the additional expense, for each raise, add to the costs obtained from the curves the following amounts:

Labor factor $(F_L) = \$1,172.00$

Supply factor $(F_S) = \$6,940.00$

To account for the absence of the overshot mucker multiply the equipment costs obtained from the curves by the following factor:

Equipment operation factor $(F_E) = 0.80$



4.2.1.5.1. Raise development
DRIVING RAISES

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.5.2. RAISE DEVELOPMENT
DROP RAISES

With the advent of down-the-hole drills, longhole or drop raising is becoming a popular method of driving large ventilation raises and ore passes. The costs estimated using these curves apply to any unlined raise driven using down-the-hole drills and vertical crater retreat blasting methods. Advance rates range from 1.5 m per worker-shift for a 4.6 m^2 raise to 1.0 m per worker-shift for a 13.4 m^2 raise. It is assumed that blasted material is hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rubber-tired LHD's. If the material is to be hauled out of the mine, the tonnage attributed to raising should be added to the haulage curves for the period of time necessary to muck the raise.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4.5 and 13.5 m^2, operating two shifts per day. The cost per meter is multiplied by the total meters of raise required for development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 58.314(X)^{0.374}$
The operating labor costs are distributed as follows:

Direct labor...............	86%
Maintenance labor..........	14%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Drillers...................	29%	$18.31
Helpers....................	15%	13.86
Blasters...................	43%	18.31
LHD operators..............	13%	16.53

The average wage for labor is $17.41 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 136.383(X)^{0.205}$
The supply cost consists of 68% blasting materials, 24% drill bits and steel, 7% miscellaneous items, and 1% timber. Supplies include drill bits and steel, blasting agent, caps, primers, detonation cord, timber, and caristrap.

(E) Equipment Operating Cost $(Y_E) = 8.895(X)^{0.711}$
The equipment operating cost consists of 43% for maintenance and overhaul parts, 41% for fuel, 9% for tires, and 7% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drop raising includes down-the-hole drills mounted on air tracks, portable air compressors, LHD units, and portable bit grinders.

ADJUSTMENT FACTORS

Rock Hardness Factor Down-hole-drill productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supplies factor $(F_S) = 0.579(C)^{0.054}$

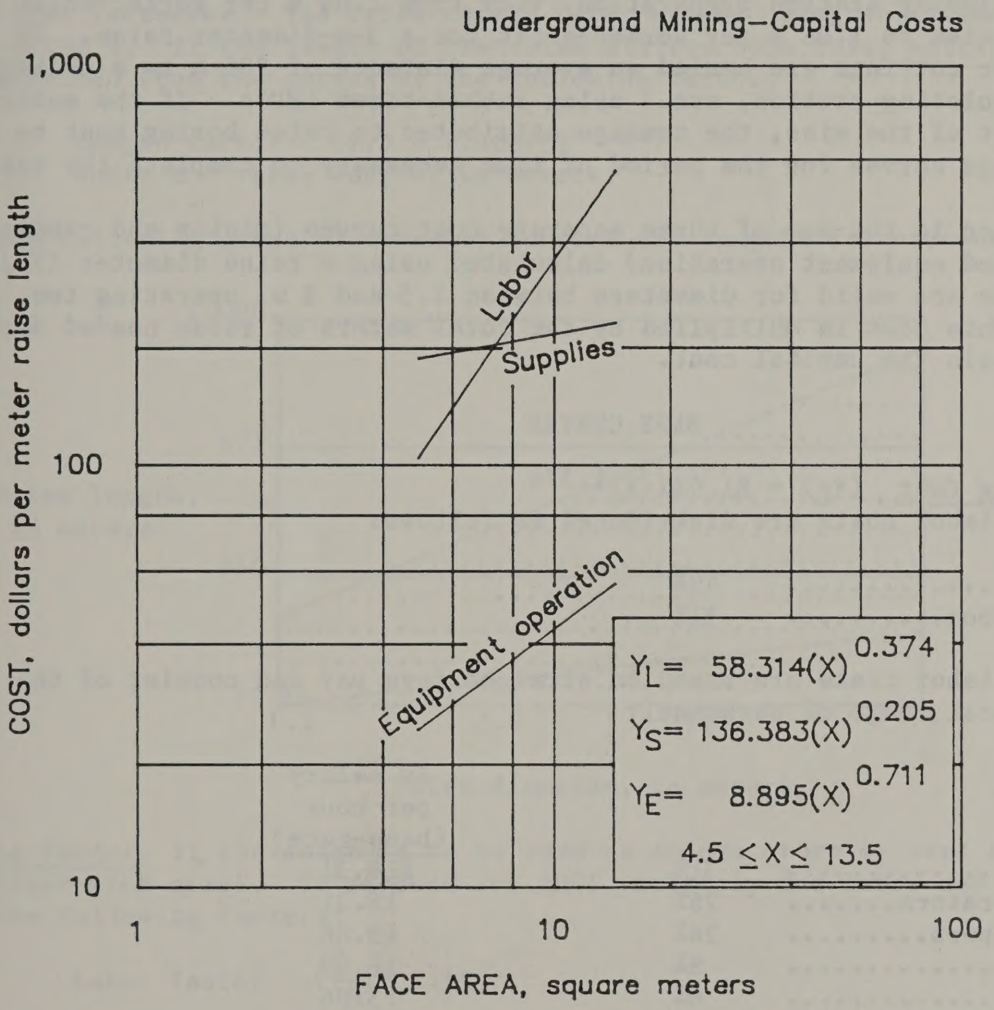
Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Service Installation Factor Few drop raises are used as service raises. If, however, services are installed in the raise, multiply the labor and supply costs by the following factors:

Labor factor $(F_L) = 1.51$

Supplies factor $(F_S) = 1.37$

This will account for the purchase and installation of rockbolts, ladders, landings, and pipe.



4.2.1.5.2. Raise development
DROP RAISES

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.5.3. RAISE DEVELOPMENT
RAISE BORING

The costs calculated using these curves apply to any unlined bored raise that has been drilled down and reamed up. The curves take into account costs incurred in preparation of upper and lower stations, drill platform construction, boring machine installation, pilot hole drilling, reaming operations, and muck removal. Average advance rates, including station preparation, vary from 1.89 m per worker-shift for a 1.5-m-diameter raise to 1.06 m per worker-shift for a 3-m-diameter raise. It is assumed that reamer cuttings are hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rubber-tired LHD's. If the material is to be hauled out of the mine, the tonnage attributed to raise boring must be added to the haulage curves for the period of time necessary to complete the raise.

Total cost per meter is the sum of three separate cost curves (mining and repair labor, supplies, and equipment operation) calculated using a raise diameter (X), in meters. The curves are valid for diameters between 1.5 and 3 m, operating two shifts per day. This cost is multiplied by the total meters of raise needed during development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 81.941(X)^{1.376}$

The operating labor costs are distributed as follows:

Direct labor...............	49%
Maintenance labor..........	51%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	31%	$18.31
Raise bore operators.......	26%	18.31
Raise bore helpers.........	26%	13.86
LHD operators..............	8%	16.09
Helpers....................	8%	13.86
Nippers....................	1%	16.09

The average wage for labor is $16.60 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 180.595(X)^{1.097}$

The supply cost consists of 83% drill and cutter bits, 5% material waste, 4% drill steel, 3% electricity, 3% blasting materials, 1% rock support, and 1% miscellaneous items. Supplies include drill bits and steel for the air legs, drill bits, cutter bits, and drill steel for the boring machine, blasting agent, caps, detonation cord, rock bolts, wire mesh, concrete, and electricity.

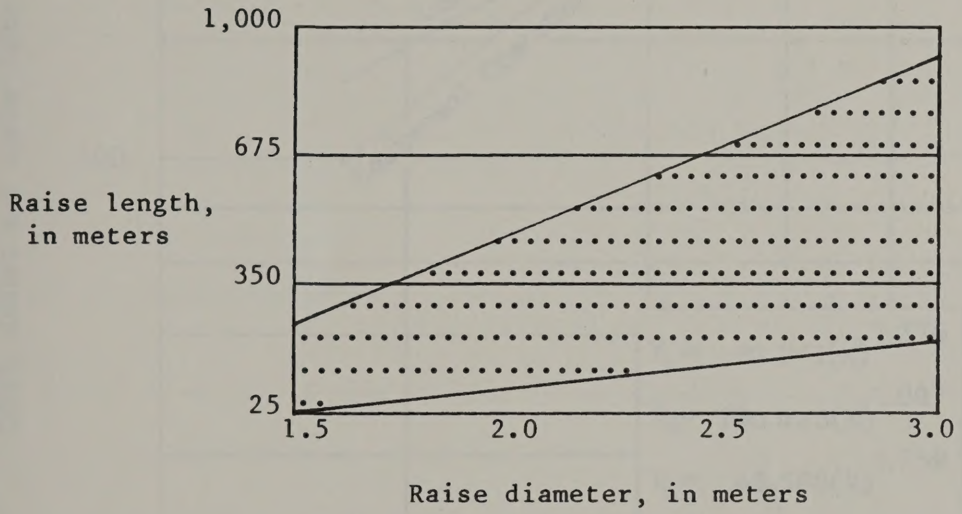
(E) Equipment Operating Cost $(Y_E) = 46.568(X)^{1.759}$
The equipment operating cost consists of 69% for maintenance and overhaul parts, 22% for ground engaging components, 7% for lubrication, and 2% for fuel and tires. The equipment curve covers overhaul and maintenance parts, ground engaging components, fuel, lubrication, and tires. The equipment used for raise boring and station preparation includes air leg drills, LHD units, and raise bore machines.

ADJUSTMENT FACTORS

Raise Length Factor Because of the high costs incurred in station preparation and machine setup, the actual cost per meter will decrease as the length of the raise increases. The raise curves were derived using an assumed raise length of 100 m. If the length of the raise differs from this, multiply the costs obtained from the curves by the following factor:

Length factor $(F_L) = 1.468(L)^{-0.080}$
where L = raise length, in meters.

The following graph illustrates recommended lengths for various raise diameters:



Lining Factor If the raise is to be used as an ore chute or vent raise, it may be lined with steel. To account for this, multiply the labor and supply costs by the following factors:

Labor factor $(F_L) = 1.12$

Supply factor $(F_S) = 1.27(X)^{0.276}$
where X = raise diameter, in meters.

Service Installation Factor If services are installed in the raise, multiply the labor and supply costs by the following factors:

Labor factor $(F_L) = 1.21$

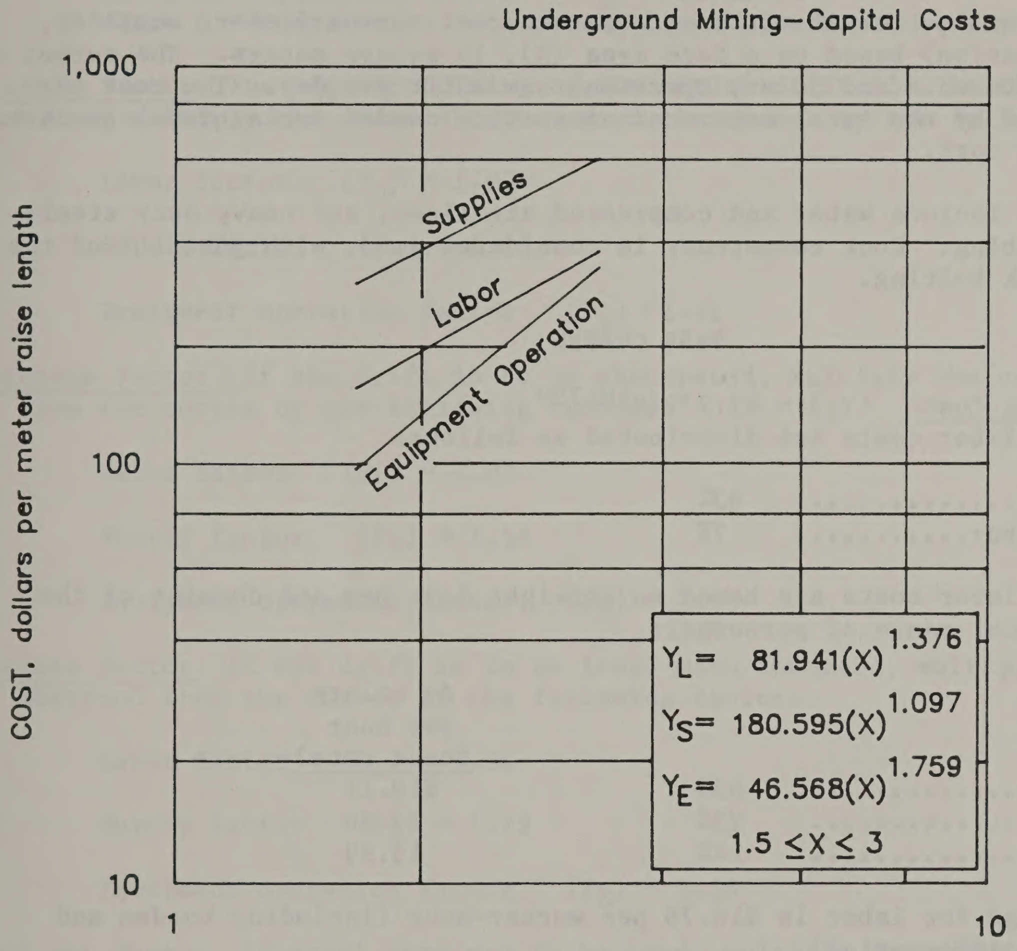
Supply factor $(F_S) = 1.16$

This will account for the purchase and installation of rockbolts, ladders, landings, and pipe.

Rock Hardness Factor The hardness of the rock being bored has a great effect on both penetration rate and cutter life. The curves were derived using rock with an assumed compressive strength of 50,000 psi. Total cost may range from 25% of the cost for rock with a compressive strength of 14,500 psi to 200% of the cost for rock with a compressive strength of 75,000 psi. Actual variances are very difficult to estimate; however, as a general rule of thumb, for differences in rock hardness, multiply the costs obtained from the curves by the following factor:

Hardness factor $(F_H) = 0.0000018(C)^{1.231}$

where C = compressive strength of rock in, pounds per square inch. See table A-1 in the appendix for average compressive rock strengths.



4.2.1.5.3. Raise development
RAISE BORING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.6. INCLINES-DECLINES

The curve covers a range of inclines-declines with average advances of 2.2 m/d in the smaller openings and 0.6 m/d overall in the larger openings. The curve is based on using jumbo drills and LHD haulage. Assume the opening is at a 10° angle. The cost per meter of advance does not change for angles 5° to 15°.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 50 m^2, operating one shift per day. The cost per meter is multiplied by the total meters of excavation needed during development to obtain the capital cost.

Services installed include water and compressed air lines, and heavy duty steel-reinforced vent tubing. Rock competency is considered good, with just 10% of the back requiring rock bolting.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 42.779(X)^{0.789}$

The operating labor costs are distributed as follows:

Direct labor...............	93%
Maintenance labor..........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners.....................	63%	$18.11
Helpers....................	23%	13.66
LHD operator...............	14%	15.89

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 48.709(X)^{0.567}$

The supply cost consists of 40% explosives, 44% steel items, and 16% miscellaneous items. Supplies include drill bits and steel, powder, caps, primer, rock-bolts, vent line, compressed air and water pipes.

(E) Equipment Operating Cost $(Y_E) = 1.498(X)^{1.303}$

The equipment operating cost consists of 49% for repair parts, 32% for fuel and lubrication, and 19% for tires. The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for drills, fans, LHD's, and other equipment used to drive the opening.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rockbolt Factor For regular bolting of the entire drift (1.2 bolts per square meter) multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.14$

Equipment operation factor $(F_E) = 1.42$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.03$

Supply factor $(F_S) = 1.24$

Equipment operation factor $(F_E) = 1.15$

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.64$

Supply factor $(F_S) = 1.72$

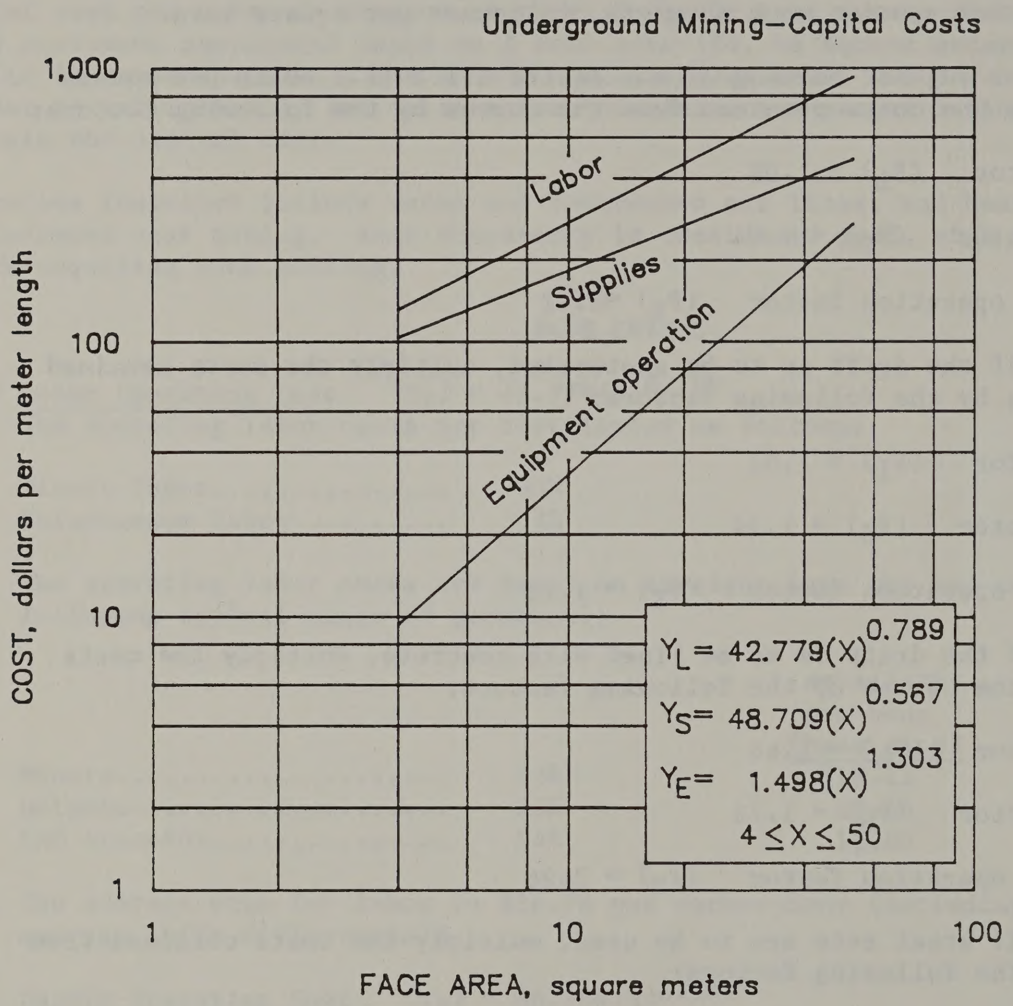
Equipment operation factor $(F_E) = 2.26$

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.37$

Supply factor $(F_S) = 2.47$

Equipment operation factor $(F_E) = 1.19$



4.2.1.6. Inclines/declines

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.7. LARGE UNDERGROUND EXCAVATIONS

The costs derived from these curves apply to a horizontal opening driven with a two boom jumbo and LHD haulage a distance of 200 m. It is assumed the walls will be supported with rockbolts and wire mesh. If the material is to be hauled out of the mine, the tonnage attributed to excavating should be added to to the haulage curves for the period of time necessary to complete the excavation. It is assumed that all equipment needed for the excavation will be required for the mining operation, and will be considered in the mine equipment cost curve.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 13.94 and 334.45 m^2, operating one shift per day. The cost per meter is multiplied by the total meters of excavation needed during development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 10.817(X)^{0.947}$
The operating labor costs are distributed as follows:

Direct labor...............	91%
Maintenance labor..........	9%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	76%	$18.11
Helpers.....................	19%	13.66
Motor operators............	5%	15.89

The average wage for labor is $17.16 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 23.050(X)^{0.793}$
The supply cost consists of 66% explosives, 28% steel items, and 6% ventilation. Supplies include drill bits and steel, powder, caps, primer cord, water pipe, compressed air pipe, vent duct, rockbolts and wire mesh.

(E) Equipment Operating Cost $(Y_E) = 1.739(X)^{0.917}$
The equipment operating cost consists of 45% for overhaul and repair parts, 35% for tires, and 20% for fuel and lubrication. The equipment operating curve covers daily maintenance and overhaul parts and lubrication for drills, fans, LHD's, and roof bolters.

ADJUSTMENT FACTORS

Track Haulage Factor If track haulage is used, the LHD will be replaced by a battery locomotive, overshot mucker, and rail cars. Rubber-tired equipment is more expensive to operate than rail-mounted equipment. Therefore, to account for cost of the equipment and installing rail, multiply the costs obtained from the curves by the following factors:

Supply factor (F_S) = 1.13

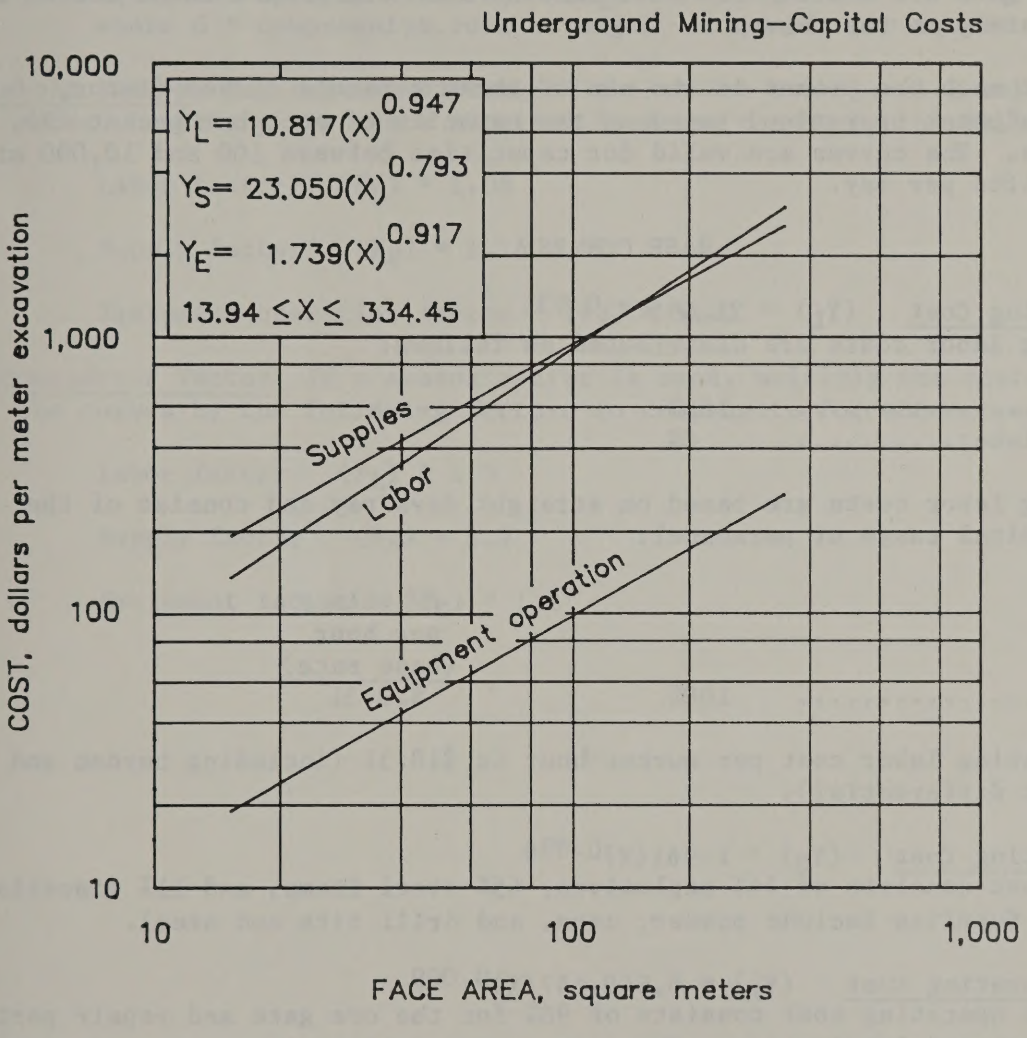
Equipment operation factor (F_E) = 0.71

Shotcrete Factor For additional expenses associated with coating the excavation to a shotcrete depth of 3.8 cm, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.05

Supply factor (F_S) = 1.59

Equipment operation factor (F_E) = 1.09



Underground Mining—Capital Costs

4.2.1.7. Large underground excavations

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.8. ORE POCKETS

The ore pocket curve is based on total capacity in metric tons. To derive the cost of an ore pocket for a given capacity, enter the capacity in metric tons. The value derived will give the cost for one ore pocket with the entered capacity. The curve is based on one pocket per entry, including the cost of excavation and the installation of a double-gate ore chute. For this reason, each ore pocket to be costed must be entered separately on the curve.

The total cost of each ore pocket is the sum of three separate curves (labor, supplies, and equipment operation) based on the capacity of each ore pocket (X), in total metric tons. The curves are valid for capacities between 100 and 10,000 mt, operating two shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 21.695(X)^{0.931}$
The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	100%	$18.31

Average operating labor cost per worker-hour is $18.31 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.961(X)^{0.994}$
The supply cost consists of 44% explosives, 45% steel items, and 11% miscellaneous items. Supplies include powder, caps, and drill bits and steel.

(E) Equipment Operating Cost $(Y_E) = 6{,}640.547(X)^{0.009}$
The equipment operating cost consists of 98% for the ore gate and repair parts, and 2% for fuel and lubrication. The cost covers daily maintenance and repair, repair parts, and lubrication for the drills and ore gates, plus the purchase of the gates.

ADJUSTMENT FACTORS

Rock Hardness Factor Productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rockbolt Factor For regular bolting of the entire pocket, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.14$

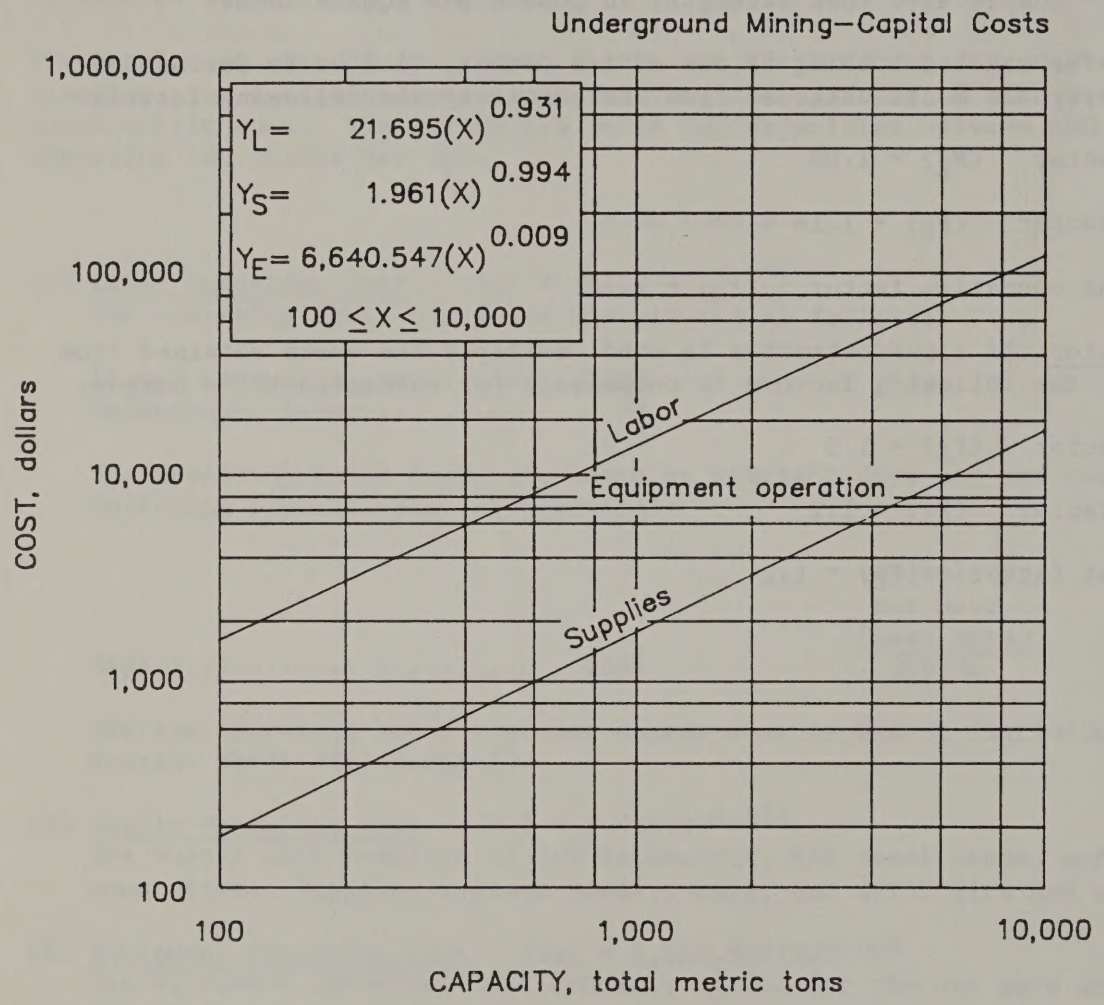
Equipment operation factor $(F_E) = 1.42$

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment factor $(F_E) = 1.2$



4.2.1.8. Ore pockets

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9. STOPE PREPARATION

Stope preparation includes any operation and excavation necessary to bring a stope into full-scale production. Stope preparation is, of course, different for every mining method, so each method is dealt with individually in the following sections In general, however, costs derived from the following curves cover every operation and excavation needed to develop the stope for full-capacity extraction, and to connect it with the main haulage system. A detailed list of items needed for individual methods is provided in each of the following sections. In order to obtain an accurate cost estimation, the evaluator must provide the dimensions and estimated tonnage of a typical stope designed for the deposit under evaluation.

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.1. STOPE PREPARATION
BLOCK CAVING

Items needed for preparation of a block caving stope include panel drifts, access drifts, grizzly drifts, undercut drifts, draw raises, transfer raises, and cave induction. All ore chutes, grizzlies, and support and reinforcement items are included in the curve. Costs represent a system in which ore is moved to the main haulage level by gravity methods.

Total cost per block is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a typical block plan view area (X), product of length and width, in square meters. The curves are valid for areas between 2,400 and 6,300 m^2 (of any height), operating two shifts per day. The costs are then multiplied by the number of blocks required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 573.198(X)^{0.881}$
The operating labor costs are distributed as follows:

Direct labor...............	98%
Maintenance labor..........	2%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners.....................	72%	$18.31
Helpers....................	24%	13.86
LHD operators..............	4%	16.09

The average wage for labor is $17.15 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 650.100(X)^{0.883}$
The supply cost consists of 26% steel items, 25% concrete, 20% timber, 18% blasting supplies, 5% contingency, 4% drill bits and steel, and 2% all other items. Supplies necessary for the development of a block caving stope include drill bits and steel, blasting agent, caps, timber, concrete, rail, water and compressed air pipe, ventilation ducting, rockbolts, electricity, and steel for ore chutes and grizzlies.

(E) Equipment Operating Cost $(Y_E) = 11.355(X)^{0.885}$
The equipment operating cost consists of 76% for maintenance and overhaul parts, 9% for tires, 8% for fuel, and 7% for lubrication. The equipment curve covers daily maintenance and overhaul parts, tires, fuel, and lubrication. Equipment

used in stope preparation for block caving includes jacklegs, auxiliary fans, overshot muckers, locomotives, ore cars, LHD's, and fan drills.

ADJUSTMENT FACTORS

Nongravity Caving Factor If the ore is to be transferred to the main haulage system using slushers or LHD's, adjustments must be made to the costs. Multiply the costs obtained from the curves by the following factors:

Slushers:

Labor factor $(F_L) = 0.85$

Supply factor $(F_S) = 0.83$

Equipment operation factor $(F_E) = 0.99$

LHD's:

Labor factor $(F_L) = 0.60$

Supply factor $(F_S) = 0.84$

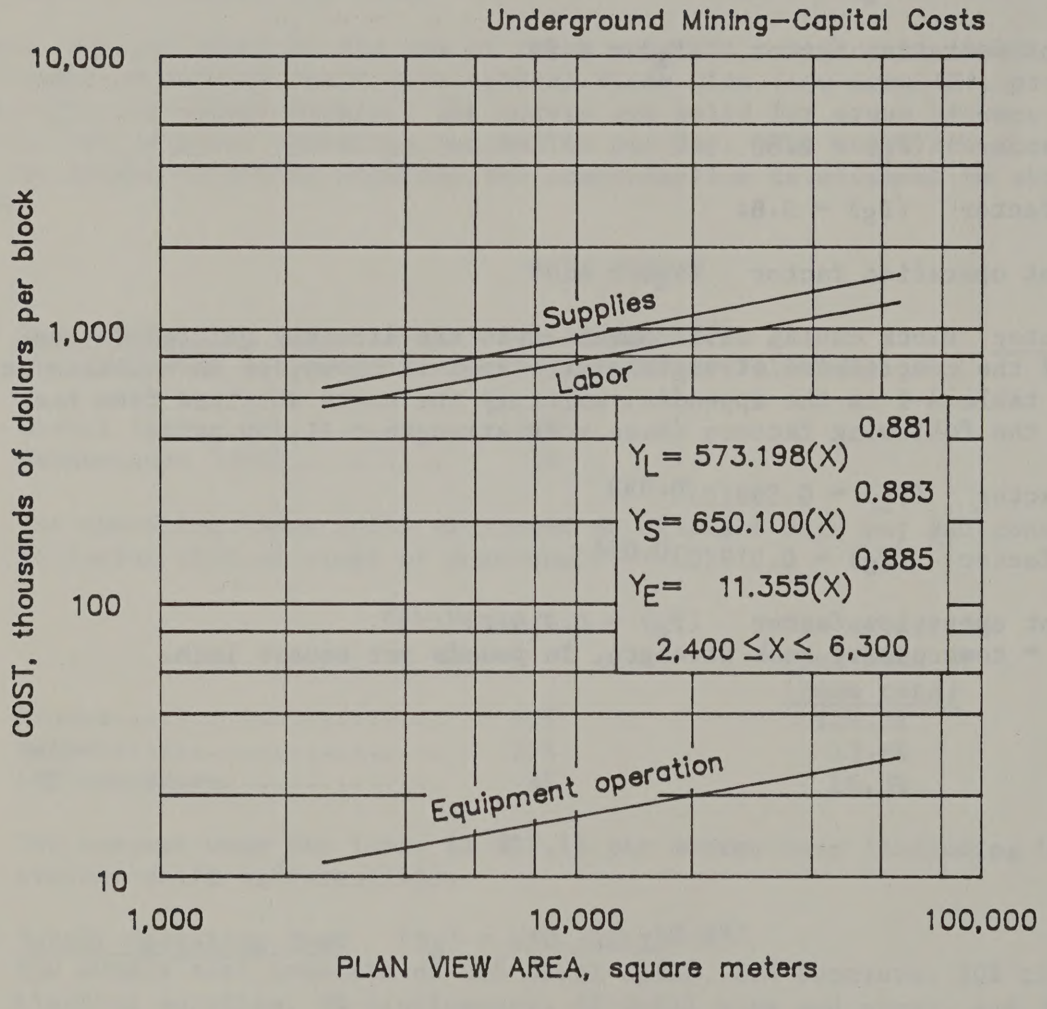
Equipment operation factor $(F_E) = 0.77$

Rock Hardness Factor Block caving development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.1. Stope preparation
BLOCK CAVING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.2. STOPE PREPARATION
CONTINUOUS MINING

Continuous miner stopes are initiated with multientry panels directly off the main haulage level. The method changes little from the initial cuts to the completion of the stope. The cost of the main haulage level cannot be included in the stope preparation costs since many stopes benefit from this one entry. Because the cost per ton of excavation of the production entries from the haulage level is the same as that for production mining, no stope preparation cost is required.

For capital cost estimation, the length of main or secondary haulageways must be sufficient to open up the required number of stopes for initial production.

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.3. STOPE PREPARATION
CUT AND FILL

Items needed for preparation of a cut-and-fill stope include a crosscut from the main haulageway, a blind raise access cut with two ore chutes, a manway, and a timber slide, and an initial bottom sill cut. The curves cover stopes ranging from 2.4 m wide by 61.0 m long to 4.9 m wide by 106.7 m long, and of any reasonable height.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 140 and 540 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 4,422.948(X)^{0.369}$
The operating labor costs are distributed as follows:

Direct labor...............	97%
Maintenance labor..........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (140 to 340 m^2)	Large (340 to 540m^2)	Av salary per hour (base rate)
Miners.....................	69%	73%	$18.31
Helpers....................	25%	23%	13.86
Motor Operators............	6%	4%	16.09

The average wage for labor is $17.13 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 16,203.090(X)^{0.197}$
The supply cost consists of 31% timber, 25% blasting supplies, 24% steel items, 5% drill bits and steel, 5% contingency, 4% ventilation material, 3% sandfill preparation material, and 3% electricity and miscellaneous items. Supplies necessary for the development of a cut-and-fill stope include drill bits and steel, blasting agent, caps, timber, rail, ballast, steel pipe, ventilation ducting, rockbolts, burlap, electricity, and steel for ore chutes.

(E) Equipment Operating Cost $(Y_E) = 311.270(X)^{0.201}$
The equipment operating cost consists of 85% for maintenance and overhaul parts, 8% for lubrication, and 7% for ground engaging components. The equipment curve covers maintenance and overhaul parts, ground engaging components, and lubrication. Equipment used in stope preparation for cut-and-fill mining includes

jacklegs, stopers, jackhammers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

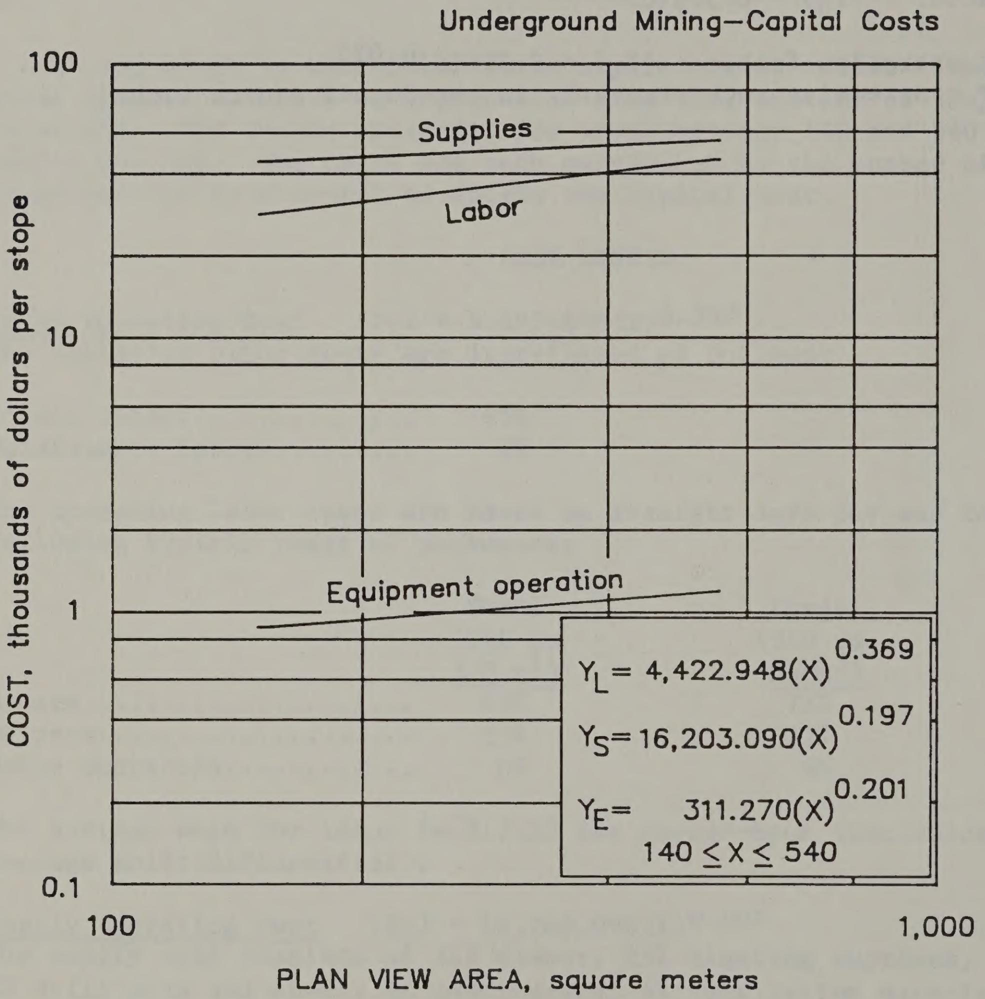
ADJUSTMENT FACTOR

Rock Hardness Factor Cut-and-fill stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.3. Stope preparation
CUT AND FILL

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.4. STOPE PREPARATION
LONGHOLE-SUBLEVEL

Items needed for preparation of a sublevel-longhole stope include sublevels, a bottom sill cut, a scram drift, crosscuts connecting the bottom sill and scram drifts, an access raise, and a slot raise. The curves cover stopes ranging from 5.4 m wide by 61.0 m high by 76.2 m long to 18.3 m wide by 121.9 m high by 152.4 m long.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a profile view area (X), product of length and height, in square meters. The curves are valid for areas between 4,600 and 18,600 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 357.256(X)^{0.685}$
The operating labor costs are distributed as follows:

Direct labor...............	95%
Maintenance labor..........	5%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (4,600 to 11,600 m^2)	Large (11,600 to 18,600 m^2)	Av salary per hour (base rate)
Miners.....................	65%	65%	$18.31
Helpers....................	22%	22%	13.86
LHD operators..............	9%	8%	16.09
Utility workers............	3%	4%	15.94
Surveyors	1%	1%	15.08

The average wage for labor is $17.05 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 363.252(X)^{0.687}$
The supply cost consists of 46% blasting supplies, 16% steel items, 10% drill bits and steel, 9% ventilation materials, 9% timber, 5% contingency, and 5% electricity and miscellaneous items. Supplies necessary for the development of a sublevel-longhole stope include drill bits and steel, blasting agent, caps, timber, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 23.555(X)^{0.707}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 19% for tires, 17% for fuel, and 7% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment

used in stope preparation for sublevel-longhole mining includes jacklegs, auxiliary fans, LHD's, booster compressors, jumbo mounted drifters, and airtrack-mounted longhole drills.

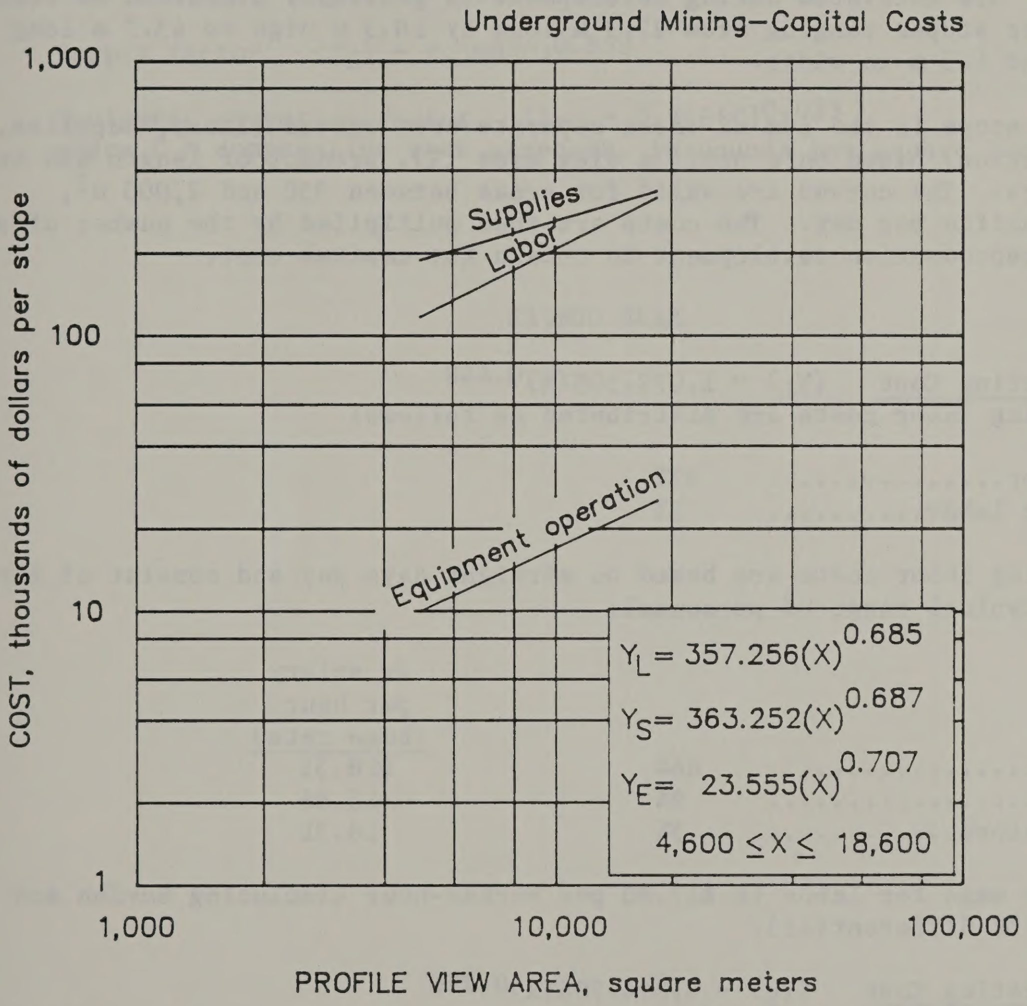
ADJUSTMENT FACTOR

Rock Hardness Factor Sublevel-longhole stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be madefrom table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.392(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.4. Stope preparation
LONGHOLE/SUBLEVEL

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.5. STOPE PREPARATION
RESUING

Items needed for preparation of a resuing stope include an access drift along the stope in the footwall, a blind raise access cut with two ore chutes and a manway, and a starter drift running the length of the stope. The blind raise runs the entire height of the stope, and both the raise and the starter drift are driven in ore and waste. Ore excavated during development is generally discarded as waste. The curves cover stopes ranging from 22.9 m long by 18.3 m high to 45.7 m long by 38.1 m high, and 1.5 m in width.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a profile view area (X), product of length and height, in square meters. The curves are valid for areas between 350 and 2,000 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 1,077.505(X)^{0.448}$
The operating labor costs are distributed as follows:

Direct labor...............	97%
Maintenance labor..........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners.....................	86%	$18.31
Helpers....................	9%	13.86
Motor operators............	5%	18.31

The average wage for labor is $17.80 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4,004.706(X)^{0.290}$
The supply cost consists of 61% steel items, 13% blasting supplies, 12% timber, 6% ventilation materials, 4% drill bits and steel, 3% contingency, and 1% electricity and miscellaneous items. Supplies necessary for the development of a resuing stope include drill bits and steel, blasting agent, caps, timber, rail, ballast, steel pipe, ventilation ducting, electricity, and steel for ore chutes.

(E) Equipment Operating Cost $(Y_E) = 24.097(X)^{0.499}$
The equipment operating cost consists of 67% for maintenance and overhaul parts, 16% for ground engaging components, 9% for fuel, and 8% for lubrication. The

equipment curve covers maintenance and overhaul parts, ground engaging components, fuel, and lubrication. Equipment used in stope preparation for resuing includes jacklegs, stopers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

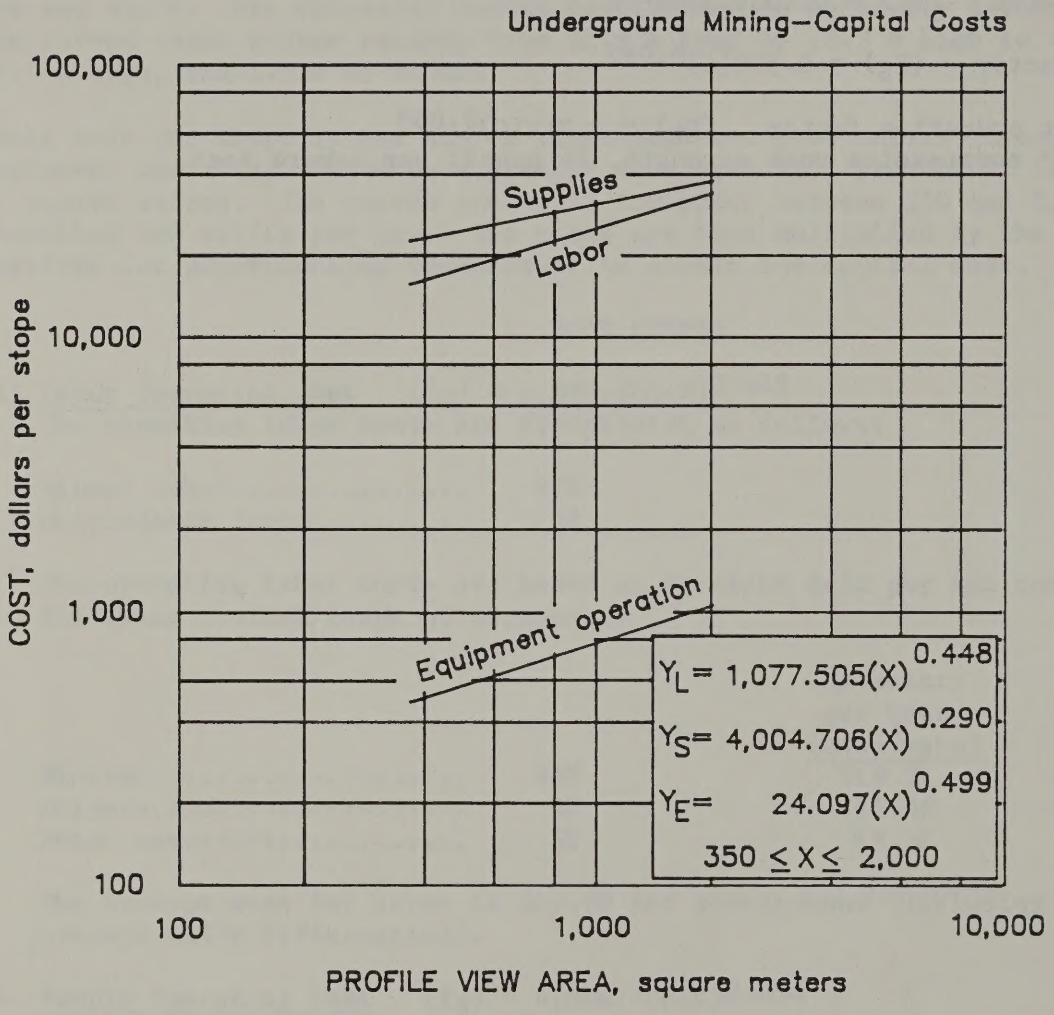
ADJUSTMENT FACTOR

Rock Hardness Factor Resuing stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.5. Stope preparation
RESUING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.6. STOPE PREPARATION
ROOM AND PILLAR, MEDIUM TO HARD ROCK

The main item needed to prepare a metallic room-and-pillar stope is an access drift from a main haulageway running the entire length of the panel.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 12,900 and 30,200 m^2 (of any reasonable height), operating two shifts per day. The costs are then multiplied by the number of panels required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 4.019(X)^{0.890}$

The operating labor costs are distributed as follows:

Direct labor...............	92%
Maintenance labor..........	8%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (12,900 to 21,500 m^2)	Large (21,550 to 30,200 m^2)	Av salary per hour (base rate)
Miners.....................	46%	43%	$18.31
Helpers....................	11%	22%	13.86
Utility workers............	15%	12%	16.98
Utility helpers............	15%	12%	13.86
Loader operators...........	7%	8%	16.53
Surveyors..................	6%	3%	15.08

The average wage for labor is $16.53 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.686(X)^{0.997}$

The supply cost consists of 58% blasting supplies, 12% steel items, 11% drill bits and steel, 10% ventilation materials, 5% contingency, and 4% electricity and miscellaneous items. Supplies necessary for the development of a metallic room-and-pillar stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation materials, electricity, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.046(X)^{1.128}$

The equipment operating cost consists of 59% for maintenance and overhaul parts, 21% for fuel, 13% for tires, and 7% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for metallic room and pillar mining includes auxiliary fans, front-end loaders, jacklegs, scissor lifts, and jumbo-mounted drifters.

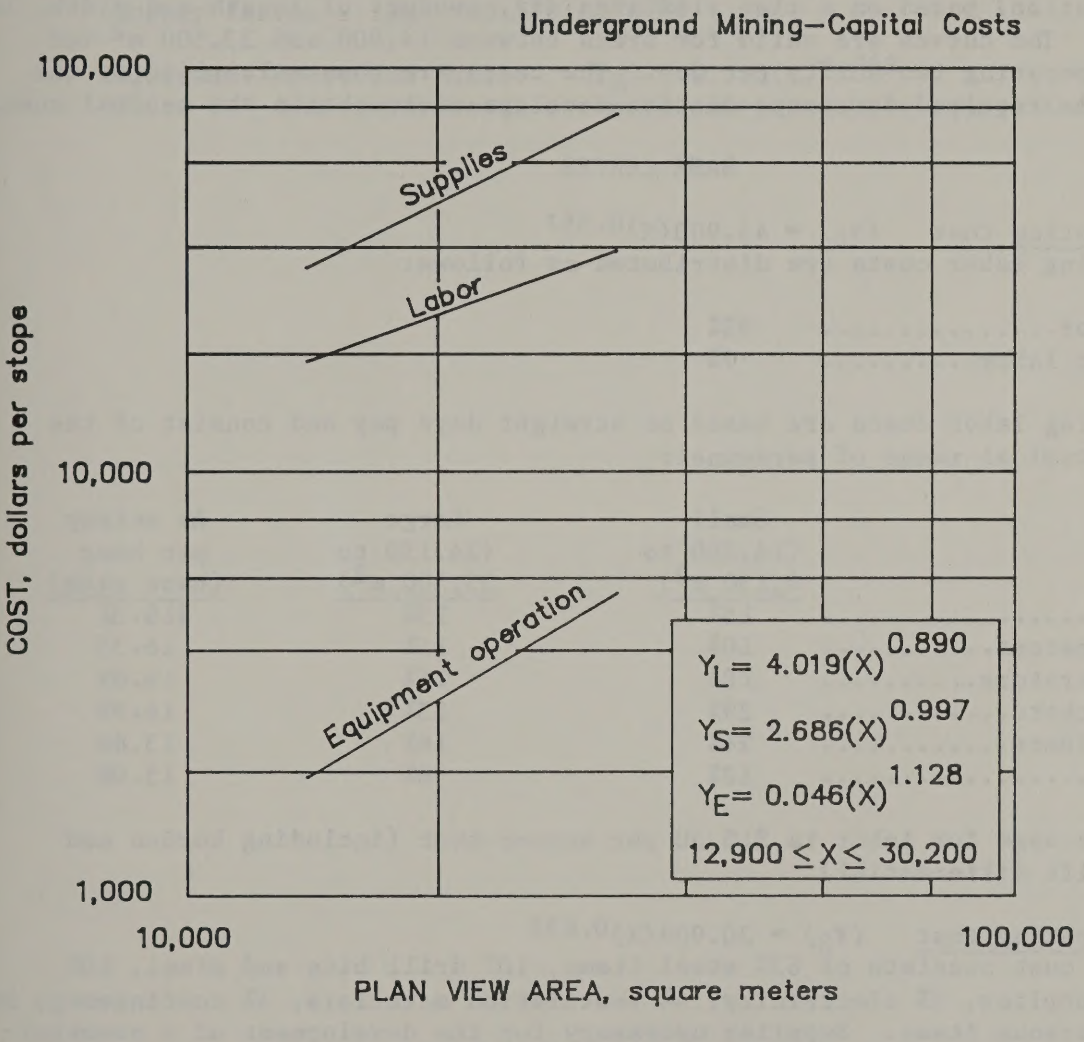
ADJUSTMENT FACTOR

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.6. Stope preparation
ROOM & PILLAR, MEDIUM TO HARD ROCK

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.7. STOPE PREPARATION ROOM AND PILLAR, NONMETALLIC SOFT ROCK

The main item needed to develop a nonmetallic room-and-pillar stope consists of an access drift from a main haulageway running the entire length of the panel.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 14,800 and 33,500 m^2 (of any height), operating two shifts per day. The costs are then multiplied by the number of panels required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 43.903(X)^{0.557}$
The operating labor costs are distributed as follows:

Direct labor...............	93%
Maintenance labor..........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (14,800 to 4,150 m^2)	Large (24,150 to 33,500 m^2)	Av salary per hour (base rate)
Miners.....................	15%	23%	$18.31
Loader operators...........	10%	15%	16.53
Shuttle operators..........	10%	15%	16.09
Utility workers............	29%	23%	16.98
Utility helpers............	24%	16%	13.86
Surveyors..................	12%	8%	15.08

The average wage for labor is $16.30 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 20.909(X)^{0.632}$
The supply cost consists of 63% steel items, 10% drill bits and steel, 10% blasting supplies, 5% electricity, 4% ventilation materials, 4% contingency, and 4% miscellaneous items. Supplies necessary for the development of a nonmetallic room-and-pillar stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation materials, electricity, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.117(X)^{0.908}$
The equipment operating cost consists of 69% for maintenance and overhaul parts, 17% for tires, 11% for lubrication, and 3% for fuel. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for nonmetallic room-and-pillar mining includes roof bolters,

ANFO trucks, undercutters, loaders, shuttle cars, portable transformers-rectifiers, and jumbo-mounted drifters.

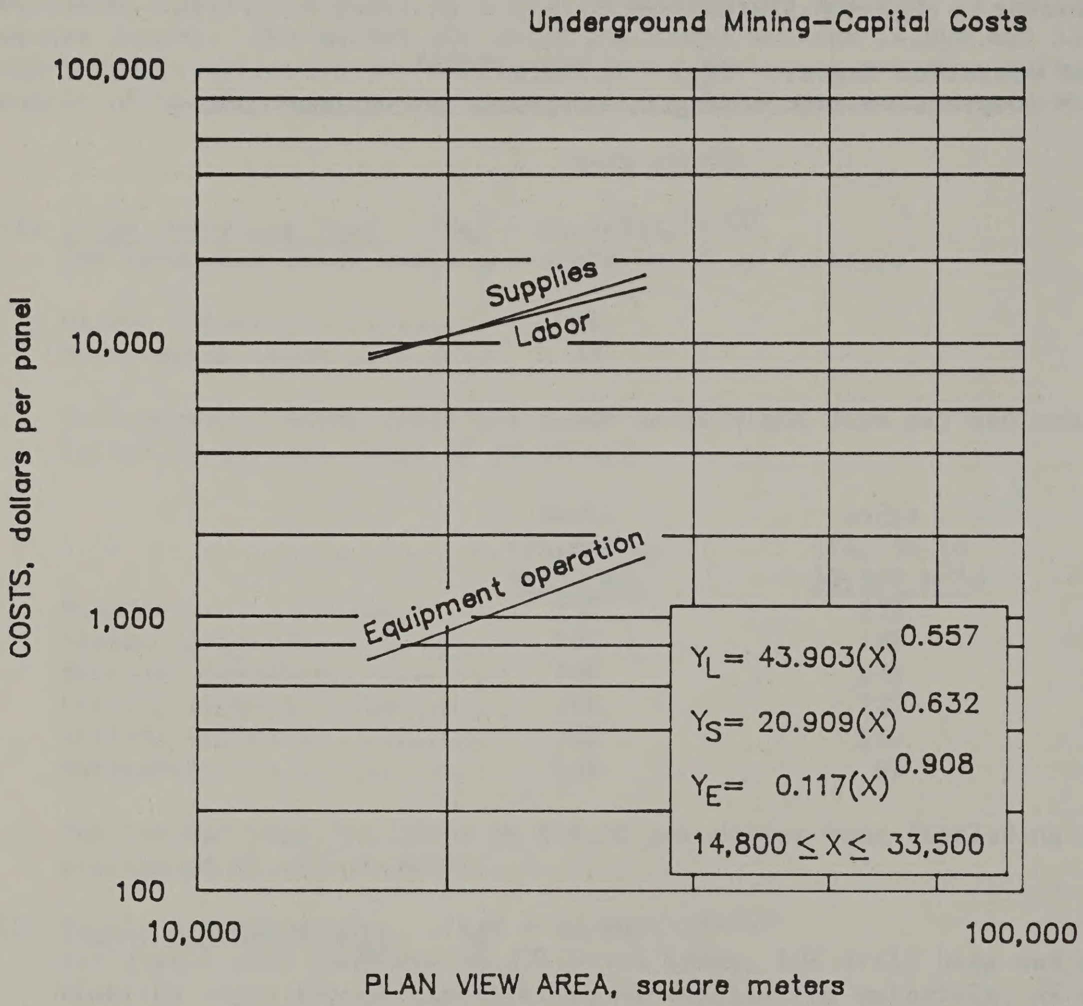
ADJUSTMENT FACTOR

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.7. Stope preparation
ROOM & PILLAR, NONMETALLIC SOFT ROCK

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.8. STOPE PREPARATION SHRINKAGE

Items needed for preparation of a shrinkage stope include a bottom sill cut, a scram drift, crosscuts from the scram to the bottom sill drift, an access raise, and dogholes along the raise to connect with the stope as mining progresses. The curves are based on the assumption that ore will be drawn from the crosscuts using LHD's. Stopes ranging from 2.4 m wide by 45.7 m long to 5.5 m wide by 76.2 m long are covered by the curve. Stope height is fixed at 61 m.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 100 and 440 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 9,917.618(X)^{0.329}$

The operating labor costs are distributed as follows:

Direct labor...............	96%
Maintenance labor..........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 270 m^2)	Large (270 to 440 m^2)	Av salary per hour (base rate)
Miners.....................	70%	65%	$18.31
Helpers....................	23%	27%	13.86
LHD operators..............	7%	8%	16.09

The average wage for labor is $17.09 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7,445.199(X)^{0.335}$

The supply cost consists of 37% blasting supplies, 19% steel items, 15% timber, 11% ventilation materials, 9% drill bits and steel, 5% contingency, and 4% electricity and miscellaneous items. Supplies necessary for the development of a shrinkage stope include drill bits and steel, blasting agent, caps, timber, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 373.610(X)^{0.388}$

The equipment operating cost consists of 64% for maintenance and overhaul parts, 20% for tires, 10% for fuel, and 6% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for shrinkage mining includes stopers, jacklegs, auxiliary fans, LHD's, and jumbo-mounted drifters.

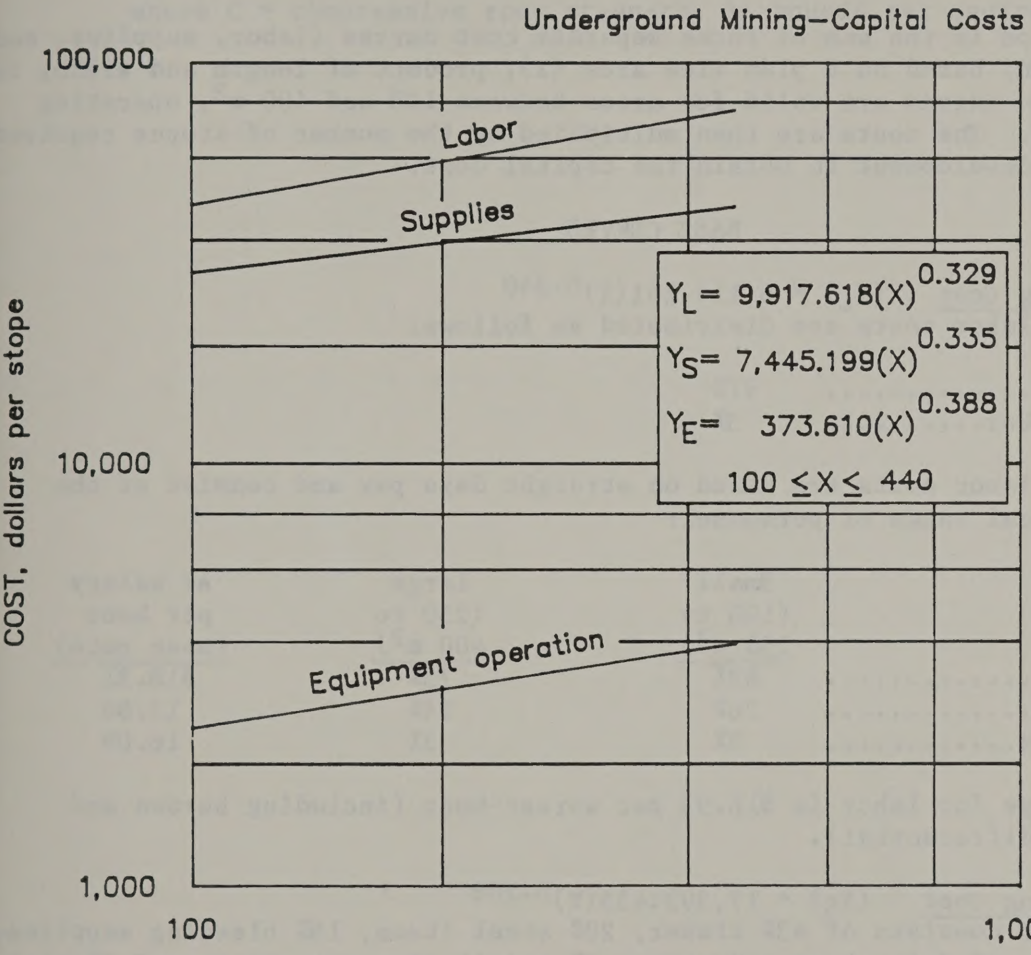
ADJUSTMENT FACTOR

Rock Hardness Factor Shrinkage stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.399(C)^{0.091}$

Supply factor $(F_S) = 0.585(C)^{0.053}$

Equipment operation factor $(F_E) = 0.717(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.8. Stope preparation
SHRINKAGE

4.2. UNDERGROUND MINING - CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.9. STOPE PREPARATION SQUARE SET

Items needed for preparation of a square set stope include a crosscut from the main haulageway, an initial bottom sill cut, and a blind raise access cut with two ore chutes, a manway, and a timber slide. The curves cover stopes ranging from 2.4 m wide by 45.7 m long to 4.9 m wide by 76.2 m long, and of any reasonable height.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 100 and 400 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 6{,}114.261(X)^{0.340}$
The operating labor costs are distributed as follows:

Direct labor...............	97%
Maintenance labor..........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 250 m^2)	Large (250 to 400 m^2)	Av salary per hour (base rate)
Miners.....................	69%	73%	$18.31
Helpers....................	26%	24%	13.86
Motor operators............	5%	3%	16.09

The average wage for labor is $16.93 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 17{,}393.433(X)^{0.208}$
The supply cost consists of 43% timber, 20% steel items, 19% blasting supplies, 9% contingency, 3% drill bits and steel, 3% ventilation materials, and 3% electricity and miscellaneous items. Supplies necessary for the development of a square set stope include drill bits and steel, blasting agent, caps, timber, blocking, rail, ballast, steel pipe, ventilation ducting, electricity, and steel for ore chutes.

(E) Equipment Operating Cost $(Y_E) = 375.160(X)^{0.178}$
The equipment operating cost consists of 83% for maintenance and overhaul parts, 10% for lubrication, and 7% for ground engaging components. The equipment curve covers maintenance and overhaul parts, ground engaging components, and lubrication. Equipment used in stope preparation for square set mining includes jacklegs, stopers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

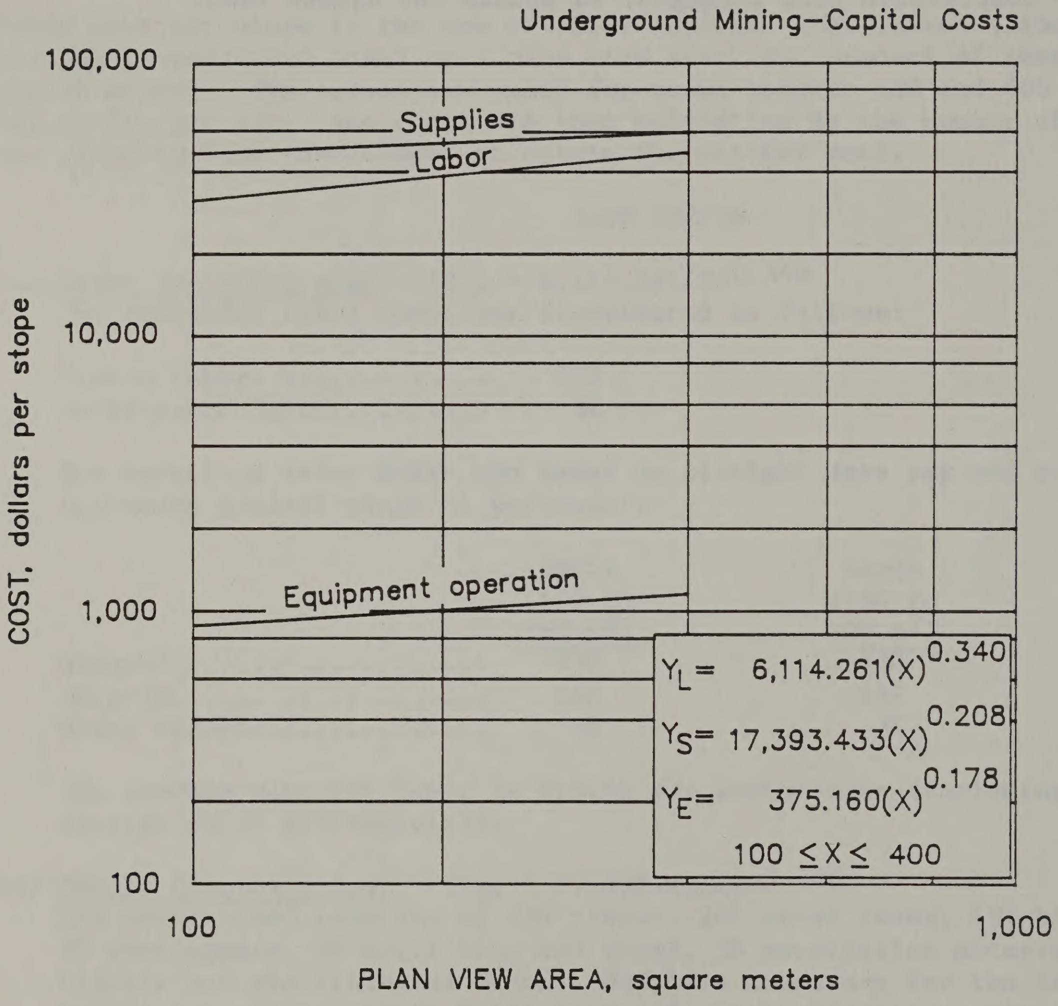
ADJUSTMENT FACTOR

Rock Hardness Factor Square set stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor (F_L) = $0.403(C)^{0.090}$

Supply factor (F_S) = $0.590(C)^{0.052}$

Equipment operation factor (F_E) = $0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.9. Stope preparation
SQUARE SET

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.9.10. STOPE PREPARATION VERTICAL CRATER RETREAT

Items needed for preparation of a vertical crater retreat stope include a topsill cut, a bottom sill cut, and access drifts. The curves are based on the assumption that, during production, ore will be drawn from the bottom sill using remote controlled LHD's. Stopes ranging from 4.6 to 11.6 m wide are covered by the curves. Stope length is estimated at 61 m, but may be varied plus or minus 25% without affecting the accuracy of the calculations. Stope height must be within the limits of down-the-hole drills.

Total cost per stope is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 250 and 750 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes required for preproduction development to obtain the capital cost.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 2{,}254.882(X)^{0.464}$

The operating labor costs are distributed as follows:

Direct labor...............	94%
Maintenance labor..........	6%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (250 to 500 m^2)	Large (500 to 750 m^2)	Av salary per hour (base rate)
Miners.....................	60%	64%	$18.31
Helpers....................	24%	23%	13.86
LHD operators..............	10%	10%	16.09
Utility workers............	4%	2%	15.42
Surveyors..................	2%	1%	15.08

The average wage for labor is $16.96 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1{,}086.699(X)^{0.642}$

The supply cost consists of 51% blasting supplies, 20% steel items, 11% drill bits and steel, 10% ventilation materials, 5% contingency, and 3% electricity and miscellaneous items. Supplies necessary for the development of a vertical crater retreat stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 10.062(X)^{0.969}$

The equipment operating cost consists of 64% for maintenance and overhaul parts, 19% for tires, 11% for fuel, and 6% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for vertical crater retreat mining includes LHD's, jacklegs, auxiliary fans, and jumbo-mounted drifters.

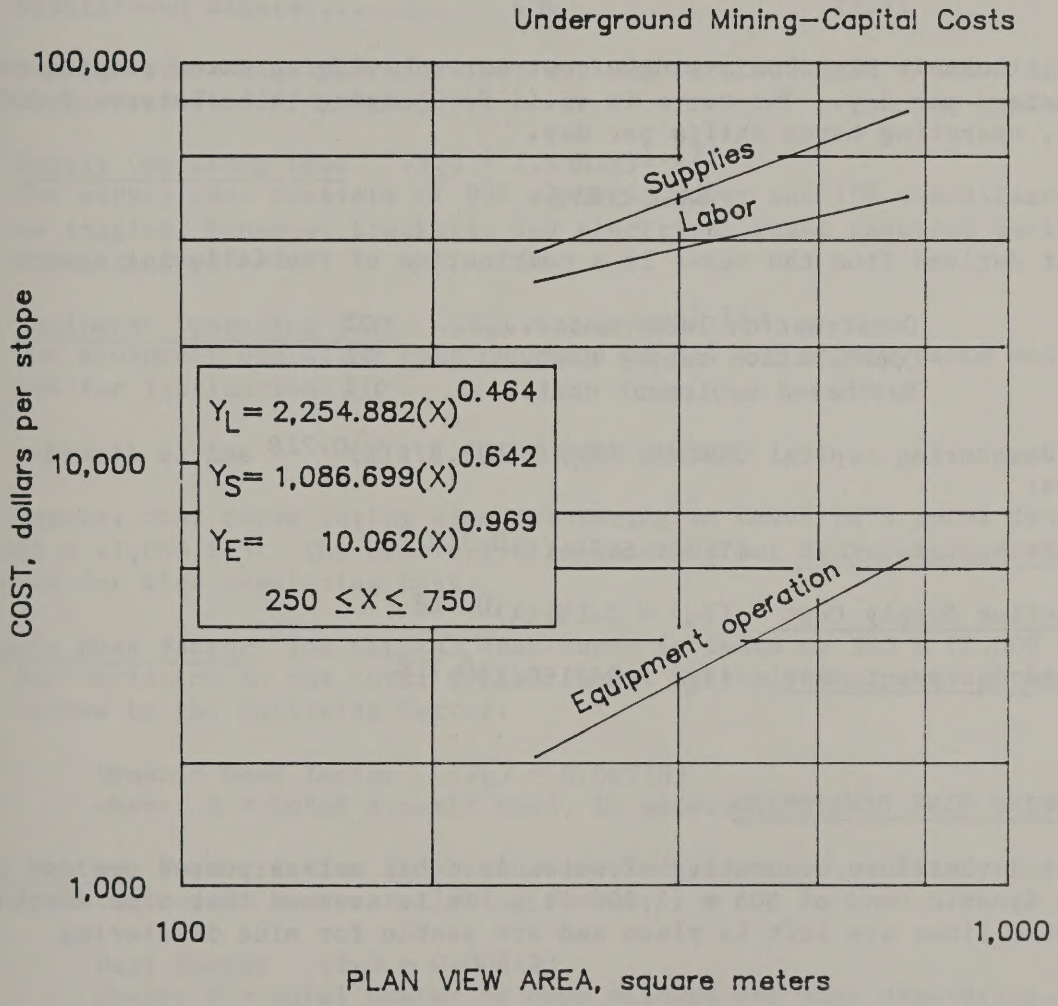
ADJUSTMENT FACTOR

Rock Hardness Factor Vertical crater retreat stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix multiply the costs obtained from curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.404(C)^{0.089}$

Supply factor $(F_S) = 0.584(C)^{0.053}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



4.2.1.9.10. Stope preparation
VERTICAL CRATER RETREAT

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.10. MINE DEWATERING

The capital cost for mine dewatering is based on the utilization of vertical turbine pumps, including the cost of acquisition and installation of equipment.

The initial capital cost is based on a quantity of water in cubic meters pumped per day against a total dynamic head of 305 m (1,000 ft). The total dynamic head is the sum of the static head, the friction loss due to pipes and fittings, and the velocity head, minus the suction head. If the suction head is negative (suction lift), its value must be added to obtain the total dynamic head. The curve includes all costs associated with the acquisition and installation of required pumps and pump bases.

The total capital cost is based on a single cost curve having an water pumping rate (X), in cubic meters per day. The curve is valid for pumping rates between 2,000 and 60,000 m^3/d, operating three shifts per day.

BASE CURVE

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	7%
Construction supply cost......	2%
Purchased equipment cost......	91%

The total mine dewatering capital cost is $(Y_C) = 103.876(X)^{0.718}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 6.544(X)^{0.718}$

(S) Construction Supply Cost $(Y_S) = 2.181(X)^{0.718}$

(E) Purchased Equipment Cost $(Y_E) = 95.150(X)^{0.718}$

CAPITAL COST DURING MINE DEWATERING

The capital cost is based on a quantity of water in cubic meters pumped per day against a total dynamic head of 305 m (1,000 ft). It is assumed that mine discharge and drilling water lines are left in place and are usable for mine dewatering purposes.

The daily cost during mine dewatering is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the the quantity of water pumped (X), in cubic meters per day. The curves are valid for quantities from 2,000 and 60,000 m^3, operating three shifts per day. The daily cost is multiplied by the total number of days allowed for dewatering the mine.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 3{,}283.826(X)^{0.368}$
The operating labor costs are distributed as follows:

Direct labor...............	82%
Maintenance labor..........	18%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Pumpman....................	42%	$15.44
Mechanics/electricians.....	15%	15.44
Underground miners.........	43%	18.11

Average operating labor cost per worker-hour is $16.58 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.438(X)^{1.177}$
The supply cost consists of 90% electric power and 10% miscellaneous items such as lagging, hangers, brackets, and electrical fuses required during the mine dewatering period.

(E) Equipment Operating Cost $(Y_E) = 0.017(X)^{1.143}$
The equipment operating cost consists of 85% for repair parts and materials and 15% for lubrication.

ADJUSTMENT FACTORS

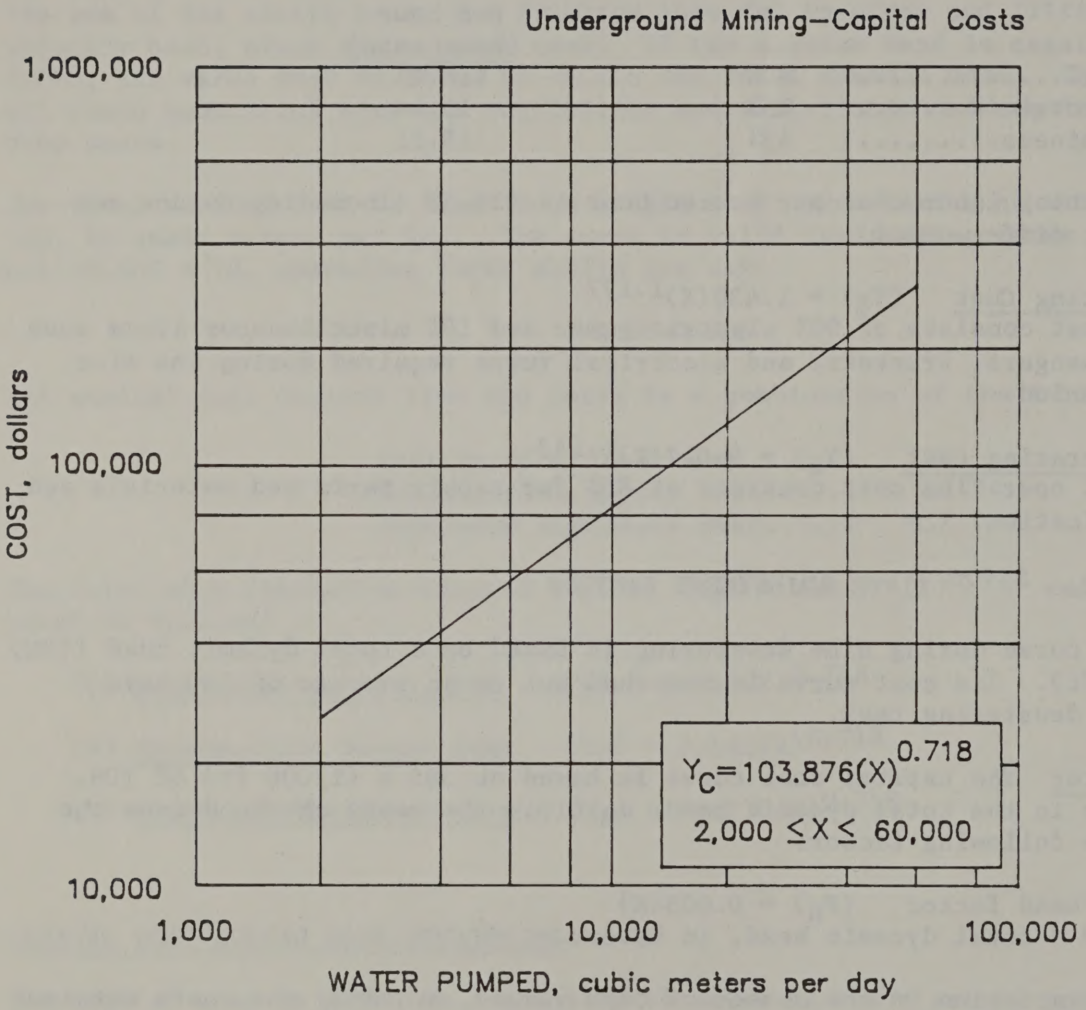
The capital cost curve during mine dewatering is based on a total dynamic head (TDH) of 305 m (1,000 ft). The cost curve is smoothed out on an average of 120 days allowed for mine dewatering task.

Dynamic Head Factor The capital cost curve is based on 305 m (1,000 ft) of TDH. For variation in the total dynamic head, multiply the costs obtained from the curves by the following factor:

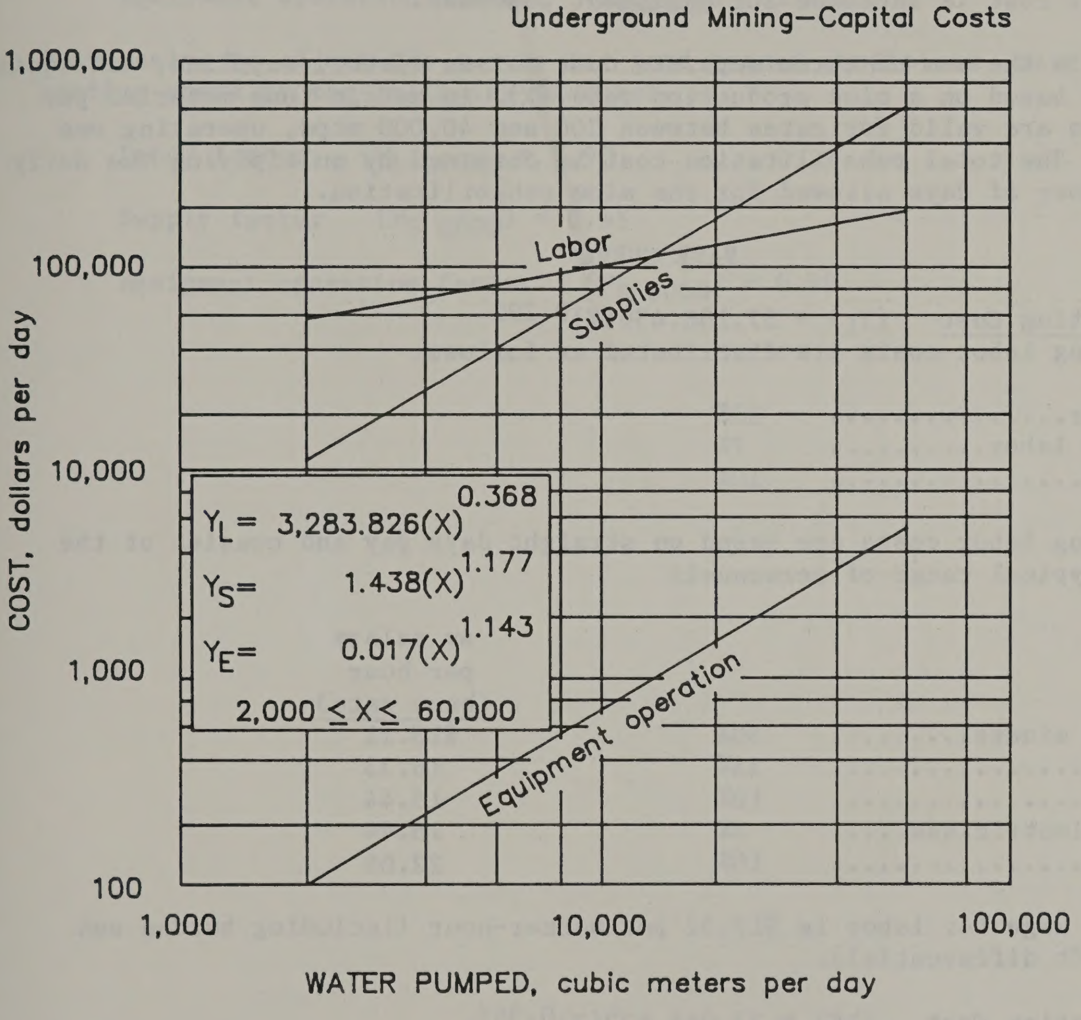
Dynamic head factor $(F_H) = 0.003(H)$
where: H = total dynamic head, in meters.

Days Factor For variation in the number of days worked, multiply the costs obtained from the curves by the following factor:

Days factor $(F_D) = 0.008(D)$
where: D = total number of days allowed for mine dewatering.



4.2.1.10.a Mine dewatering



4.2.1.10.b Mine dewatering

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.1. PREPRODUCTION DEVELOPMENT

4.2.1.11. MINE REHABILITATION

The capital cost for mine rehabilitation is based on the assumption that the mine equipment and surface mine plant have been maintained under a minimal repair and maintenance schedule and are functional prior to rehabilitation activities; therefore, no capital cost is included for equipment purchase.

The total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a mine production rate (X), in metric tons material per day. The curves are valid for rates between 200 and 40,000 mtpd, operating one shift per day. The total rehabilitation cost is obtained by multiplying the daily cost by the number of days allowed for the mine rehabilitation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 37{,}186.450(X)^{0.292}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	7%
Supervision................	10%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Underground miners.........	50%	$18.11
LHD Miners.................	23%	16.33
Hoistman...................	10%	15.44
Mechanics/electricians.....	7%	15.44
Supervision................	10%	22.08

The average wage for labor is $17.52 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(YS) = 23{,}064.633(X)^{0.367}$.
The supply cost consists of 49% electric power cable, 34% ground support, 7% electric power, 2% blasting agent and caps, and 8% miscellaneous items. The miscellaneous items include small tools, ventilation duct, hose, pipe and valves, etc.

(E) Equipment Operating Cost $(YE) = 1{,}510.633(X)^{0.438}$.
The equipment operating cost consists of 89% for repair parts and materials, 5% for lubrication, and 6% for miscellaneous costs. The miscellaneous costs consist of ancilliary equipment operation such as mine hoist, compressed air, and mine ventilation plant needed during mine rehabilitation.

ADJUSTMENT FACTORS

Ground Conditions Factors The cost curves for mine rehabilitation are based on fair ground conditions. To adjust the curves for poor ground conditions, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_{L\ POOR}) = 1.25$

Supply factor $(F_{S\ POOR}) = 1.11$

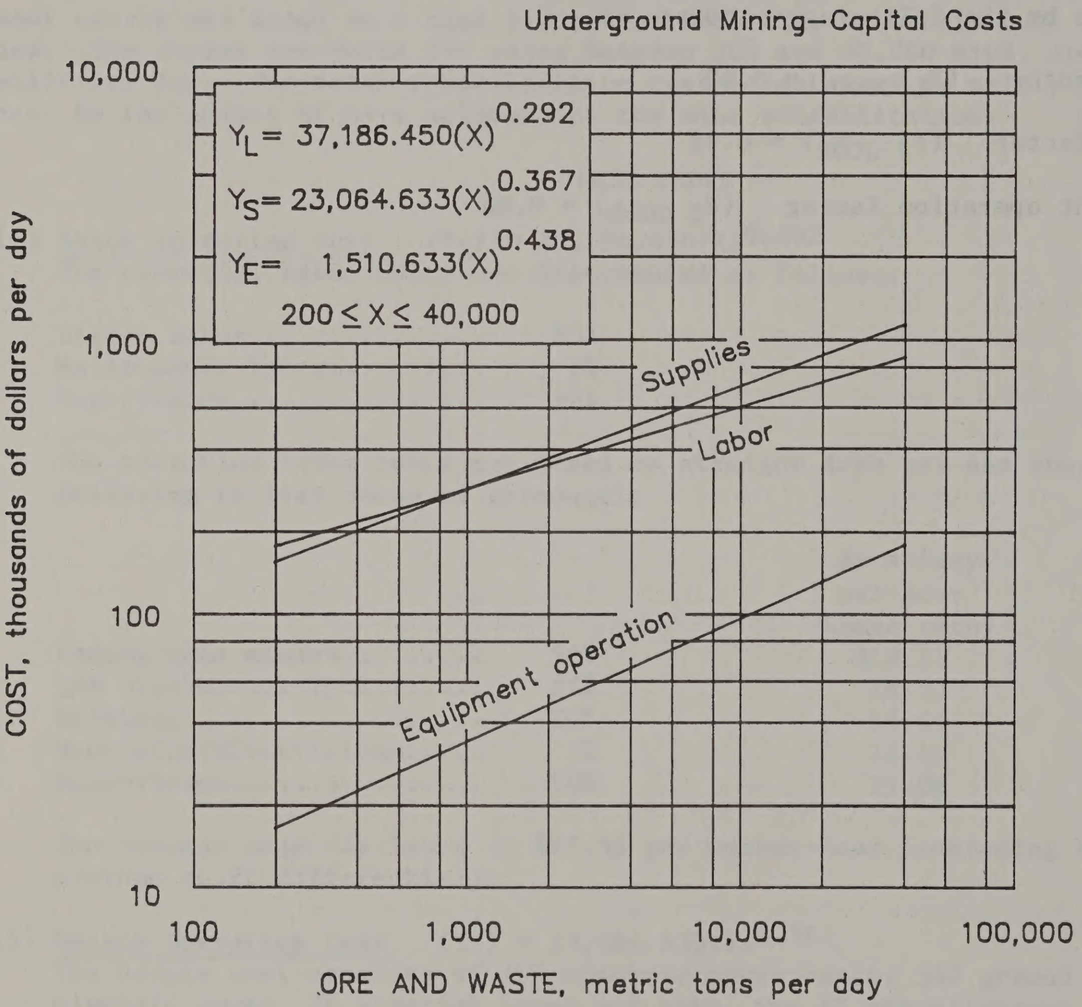
Equipment operation factor $(F_{E\ POOR}) = 1.25$

Conversely, to adjust the curves for good ground conditions, multiply the operating costs by the following factors:

Labor factor $(F_{L\ GOOD}) = 0.90$

Supply factor $(F_{S\ GOOD}) = 0.95$

Equipment operation factor $(F_{E\ GOOD}) = 0.90$



4.2.1.11. Mine rehabilitation

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.1. HOISTING FACILITIES

Selection of a mine hoist involves consideration of three sophisticated systems: mechanical, electrical, and the mine shaft. Each of these systems are dependent on numerous variables that are site-specific for each hoisting operation. To reduce complexities involved in determining capital costs, this section will deal with the two most common hoisting systems, double-drum and friction hoists.

When selecting the type of hoisting system, the estimator should consider the following:

1. Double-drum hoists are applicable to multilevel hoisting for all sizes of mines.
2. Friction hoists are applicable for deep level (+915 m) and/or single level hoisting.
3. Mines that hoist over 4,000 mtpd often have more than one hoist (i.e., one hoist may haul ore and waste and one hoist may be used for servicing the mine). The costs are only applicable for one hoist. If more than one hoist is required, recalculate the curve(s) for each additional hoist (see ADJUSTMENTS for service hoists).
4. Mines that hoist over 20,000 mtpd typically have more than one production hoist in conjunction with at least one service hoist.
5. In choosing a hoisting system it is best to remember that these facilities are usually designed for a higher capacity than required. This is especially true for smaller mines or mines anticipating an increase in capacity (i.e. a hoist operating at 100 mtph may have a design capacity of 200 mtph).
6. Single hoist mines typical hoist muck for about 80% of the daily schedule (i.e., 13 h of a 16 h work day), the remaining 20% of the schedule is devoted to transporting personnel and supplies and performing maintenance. Mines serviced by more than one production hoist typically hoist muck about 90% of the daily schedule.

BASE CURVE

The total capital cost is based on two single cost curves having a design capacity (X), in metric tons of ore and waste hoisted per hour. The curve is valid for capacities between 100 and 800 mtph. The curve includes costs associated with purchasing and erecting head frame, hoist house, hoist equipment, and ore and waste surge bins. Cost of collar foundation work and shaft loading pockets are covered in the section on shafts.

The capital cost derived from the curve is a combination of the following costs:

Double-drum hoist

Construction labor cost.......	20%
Construction supply cost......	43%
Purchased equipment cost......	37%

Friction hoist

Construction labor cost.......	18%
Construction supply cost......	30%
Purchased equipment cost......	52%

The total double-drum hoisting facility capital cost is $(Y_{C\ \mathrm{DOUBLE\text{-}DRUM}}) = 12{,}131.769(X)^{1.026}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{DOUBLE\text{-}DRUM}}) = 2{,}426.354(X)^{1.026}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{DOUBLE\text{-}DRUM}}) = 5{,}216.661(X)^{1.026}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{DOUBLE\text{-}DRUM}}) = 4{,}488.754(X)^{1.026}$

The total friction hoisting facility capital cost is $(Y_{C\ \mathrm{FRICTION}}) = 9{,}279.338(X)^{0.918}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{FRICTION}}) = 1{,}670.281(X)^{0.918}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{FRICTION}}) = 2{,}783.801(X)^{0.918}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{FRICTION}}) = 4{,}825.256(X)^{0.918}$

ADJUSTMENT FACTORS

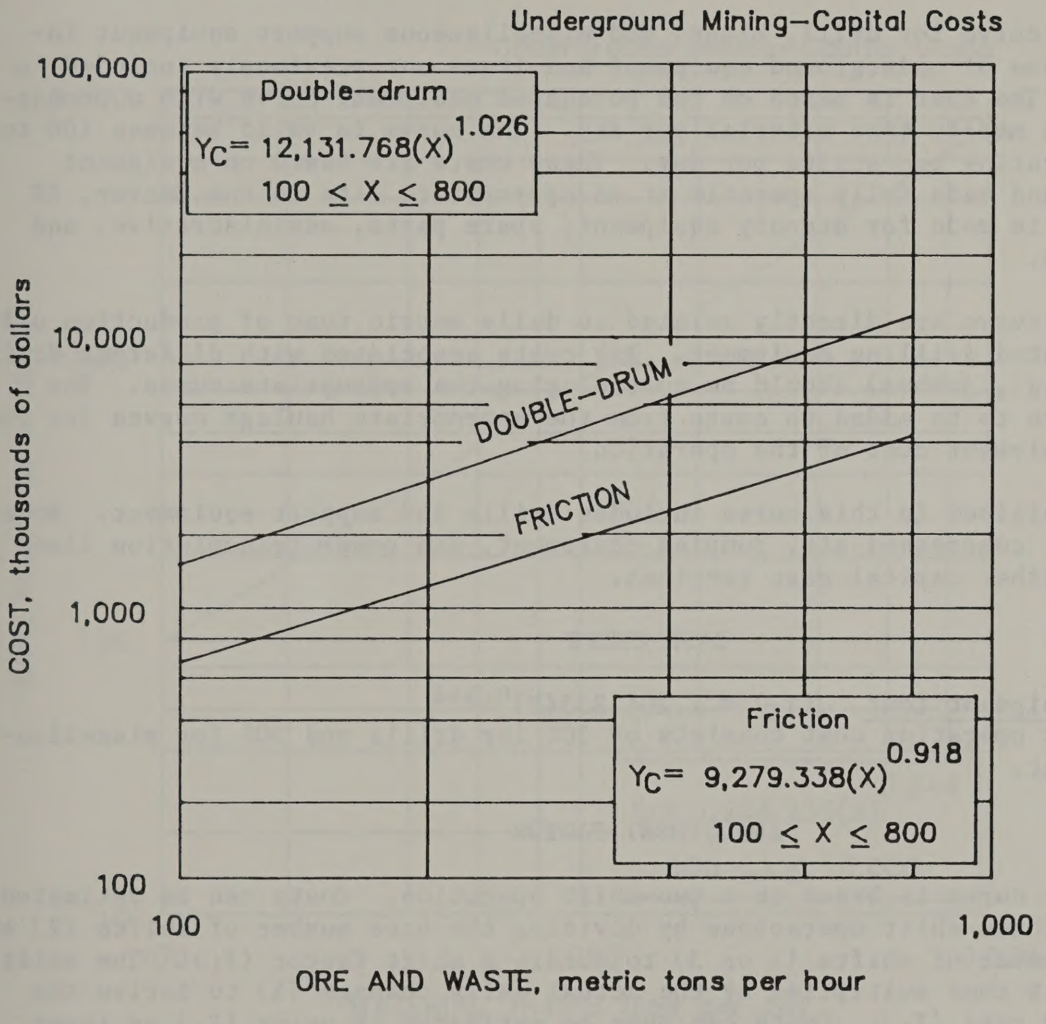
Depth Factor To determine the capital cost for hoist facilities whose maximum hoist depth varies from 915 m (3,000 ft), multiply the cost obtained from the curve by the following factor:

Double-drum hoist:
Depth factor $(F_D) = 0.094(D)^{0.345}$

Friction hoist:
Depth factor $(F_D) = 0.112(D)^{0.322}$
where D = maximum hoisting depth from surface, in meters.

Service Hoist If a hoist is to be used for service hoisting only (typical for operations which the production hoist is over 4,000 mtpd), enter the nonproduction hoist curve at 33% the production hoist capacity and use this value in the hoisting equations.

Service hoist $(X_S) = 0.33(X)$



4.2.3.1. Hoisting facilities

4.2.3.2.1. DRILL, BLAST, AND MISCELLANEOUS EQUIPMENT
JACKLEGS

This section covers costs associated with a mine using jacklegs, stopers, and drifters as their primary drill equipment. For mines using jumbos as their primary drill equipment, refer to section 4.2.3.2.2.

The capital cost curve for drill, blast, and miscellaneous support equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a production rate (X), in metric tons material per day. The curve is valid between 100 to 10,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

The costs on the curve are directly related to daily metric tons of production using jacklegs and related drilling equipment. Any costs associated with different drilling equipment (e.g., jumbos) should be costed using the appropriate curve. The drilling costs are to be added to costs from the appropriate haulage curves for the total capital equipment cost of the operation.

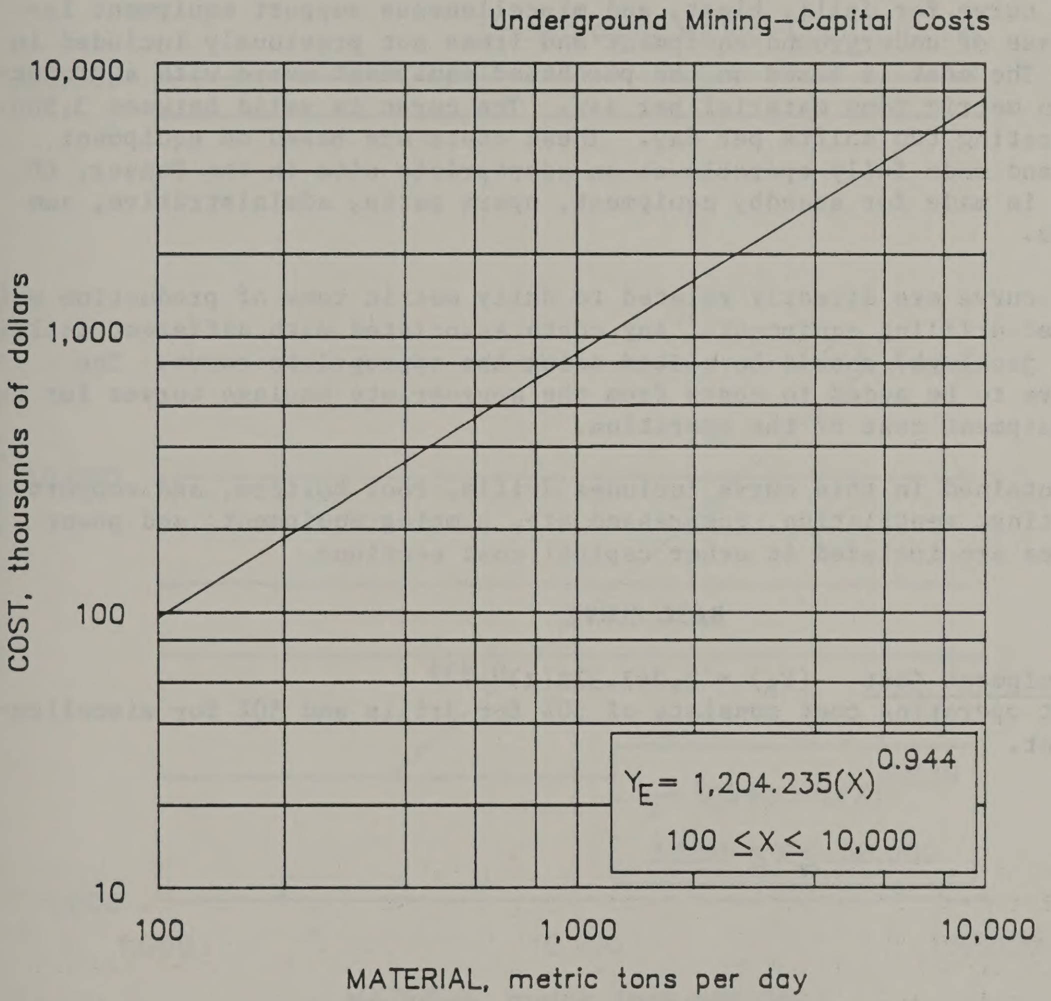
The equipment contained in this curve includes drills and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 1,204.235(X)^{0.944}$
The equipment operating cost consists of 50% for drills and 50% for miscellaneous equipment.

ADJUSTMENT FACTOR

Shift Factor The curve is based on a two-shift operation. Costs can be estimated for one- or three-shift operations by dividing the base number of shifts (2) by the actual number of shifts (1 or 3) to obtain a shift factor (F_1). The shift factor (F_1) is then multiplied by the actual daily tonnage (X) to derive the adjusted feed rate (X_1). Costs can then be estimated by using (X_1) as input to the equation.



4.2.3.2.1. Drill, blast, and misc. equipment
JACKLEGS

4.2.3.2.2. DRILL, BLAST, AND MISCELLANEOUS EQUIPMENT JUMBOS

This section covers costs associated with a mine using jumbos as their primary drill equipment. For mines using jacklegs, stopers, and drifters as their primary drill equipment, refer to section 4.2.3.2.1.

The capital cost curve for drill, blast, and miscellaneous support equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a production rate (X), in metric tons material per day. The curve is valid between 3,500 to 50,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

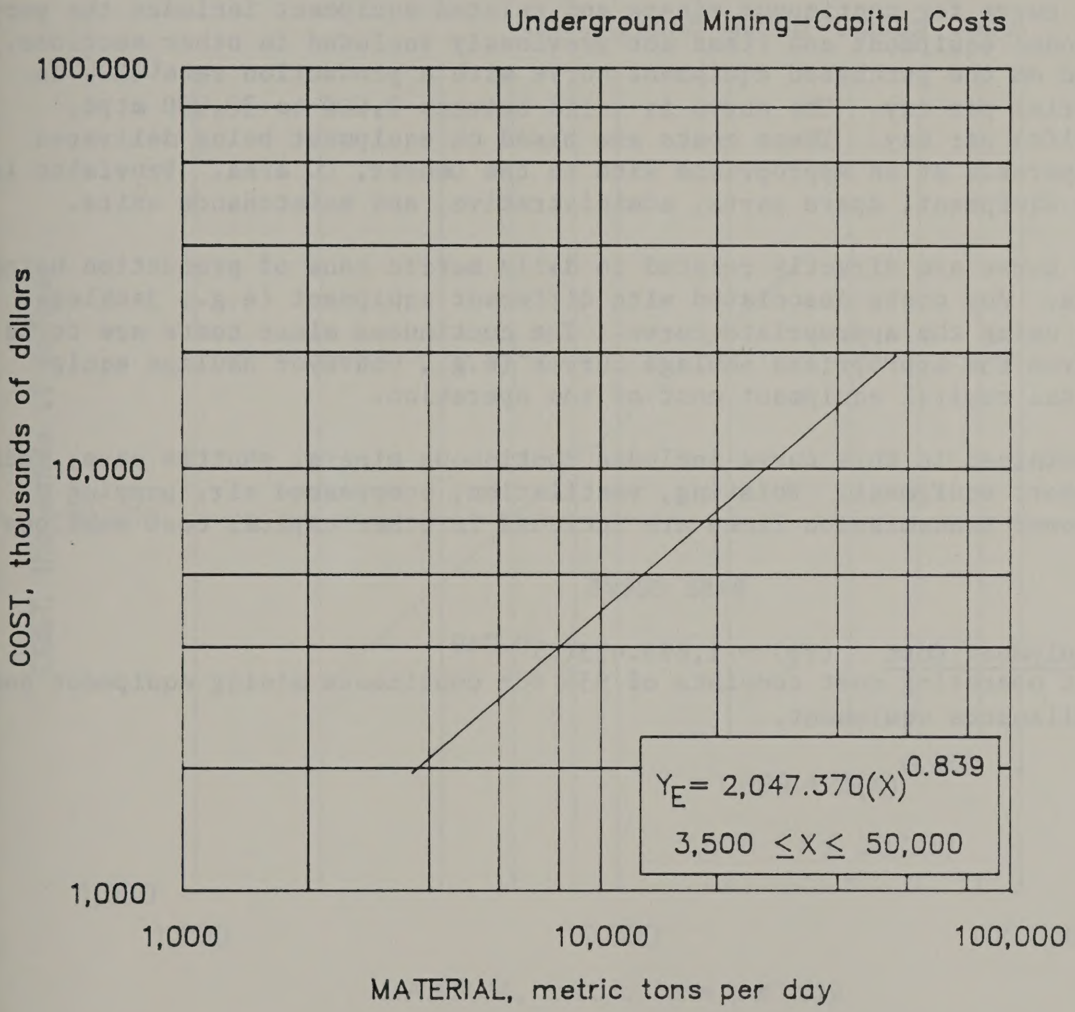
The costs on the curve are directly related to daily metric tons of production using jumbos and related drilling equipment. Any costs associated with different drilling equipment (e.g., jacklegs) should be costed using the appropriate curve. The drilling costs are to be added to costs from the appropriate haulage curves for the total capital equipment cost of the operation.

The equipment contained in this curve includes drills, roof bolters, and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 2,047.370(X)^{0.839}$

The equipment operating cost consists of 50% for drills and 50% for miscellaneous equipment.



4.2.3.2.2. Drill, blast, and misc. equipment
JUMBOS

4.2. UNDERGROUND MINING-- CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.3. CONTINUOUS MINERS

This section covers costs associated with a mine using continuous miners, shuttle cars, and rock bolters. Costs in this curve cover the use of shuttle cars to move the ore (about 100 m) to a conveyor loading point. The costs associated with the conveyor haulage equipment are covered in sections 4.2.3.5. and 4.2.3.6.

The capital cost curve for continuous miners and related equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a production rate (X), in metric tons material per day. The curve is valid between 2,000 to 30,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

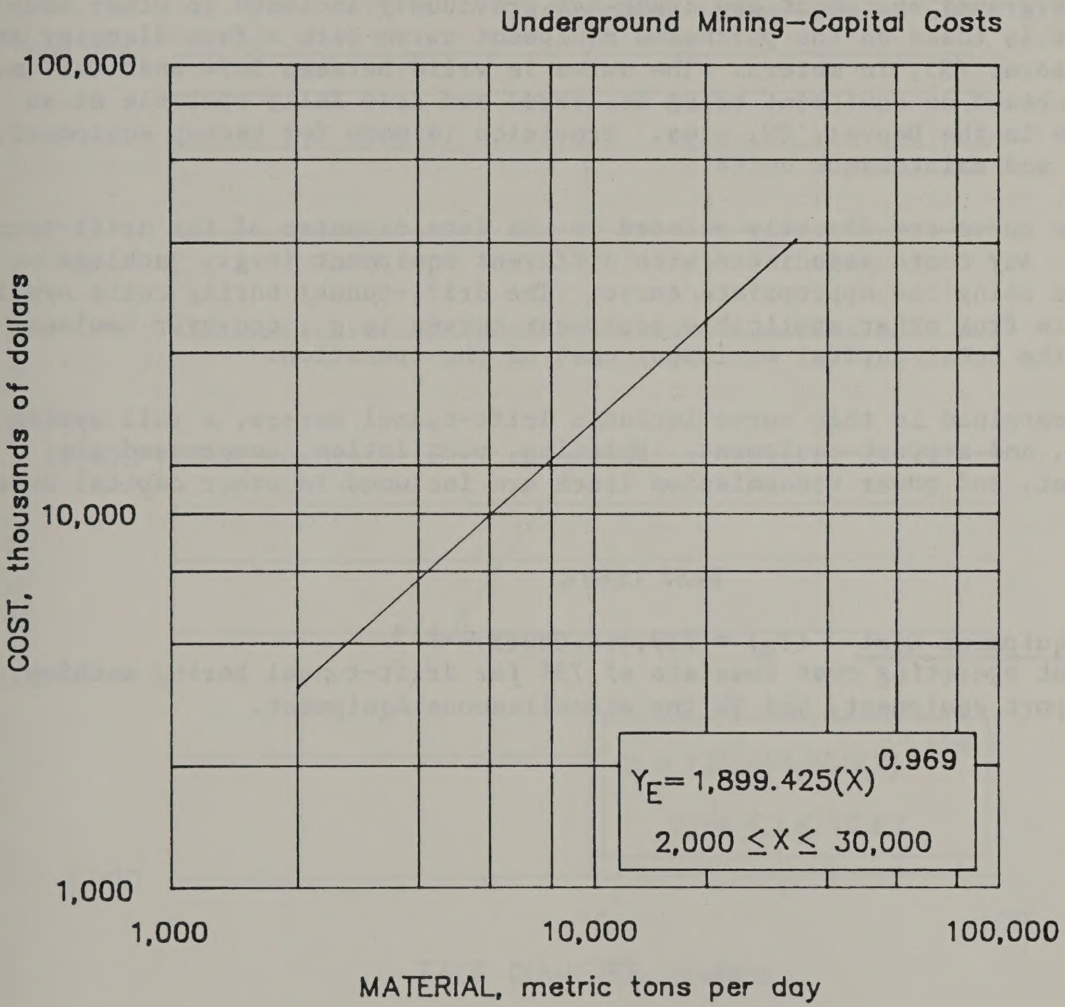
The costs on the curve are directly related to daily metric tons of production using continuous miners. Any costs associated with different equipment (e.g., jacklegs) should be costed using the appropriate curve. The continuous miner costs are to be added to costs from the appropriate haulage curves (e.g., conveyor haulage equipment) for the total capital equipment cost of the operation.

The equipment contained in this curve includes continuous miners, shuttle cars, rock bolters, and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 1{,}899.425(X)^{0.969}$

The equipment operating cost consists of 95% for continuous mining equipment and 5% for miscellaneous equipment.



4.2.3.3. Continuous miners

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.4. DRIFT-TUNNEL BORING MACHINES

This section covers costs associated with a mine using drift-tunnel boring and associated equipment. Costs in this curve cover the use of rail cars to move the material.

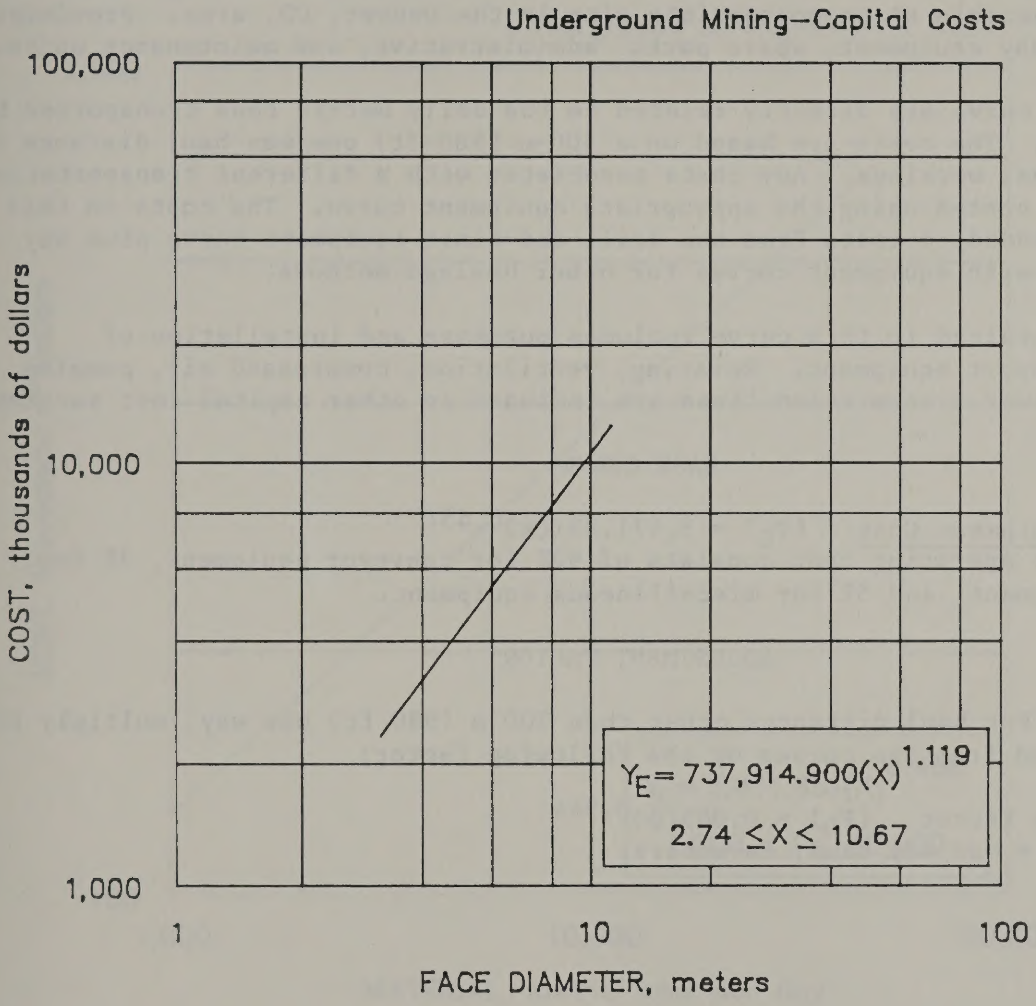
The capital cost curve for drift-tunnel boring and related equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a face diameter excavated by the borer (X), in meters. The curve is valid between 2.74 and 10.67 m. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for backup equipment, administrative, and maintenance units.

The costs on the curve are directly related to the face diameter of the drift-tunnel boring machine. Any costs associated with different equipment (e.g., jacklegs) should be costed using the appropriate curve. The drift-tunnel boring costs are to be added to costs from other applicable equipment curves (e.g., conveyor haulage equipment) for the total capital equipment cost of the operation.

The equipment contained in this curve includes drift-tunnel borers, a rail system for the machine, and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 737{,}914.900(X)^{1.119}$
The equipment operating cost consists of 75% for drift-tunnel boring machine, 16% for support equipment, and 9% for miscellaneous equipment.



4.2.3.4. Drift/tunnel boring machine

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.5. CONVEYOR HAULAGE EQUIPMENT

The capital cost curve for conveyor haulage equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a production range (X), in metric tons material per day. The curve is valid between 1,000 and 50,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

The costs on the curve are directly related to the daily metric tons transported by conveyor haulage. The costs are based on a 300-m (980-ft) one-way haul distance in level to near-level workings. Any costs associated with a different transportation method should be costed using the appropriate equipment curve. The costs on this curve are to be added to costs from the drill-and-blast equipment curve plus any costs associated with equipment curves for other haulage methods.

The equipment contained in this curve includes purchase and installation of conveyors and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

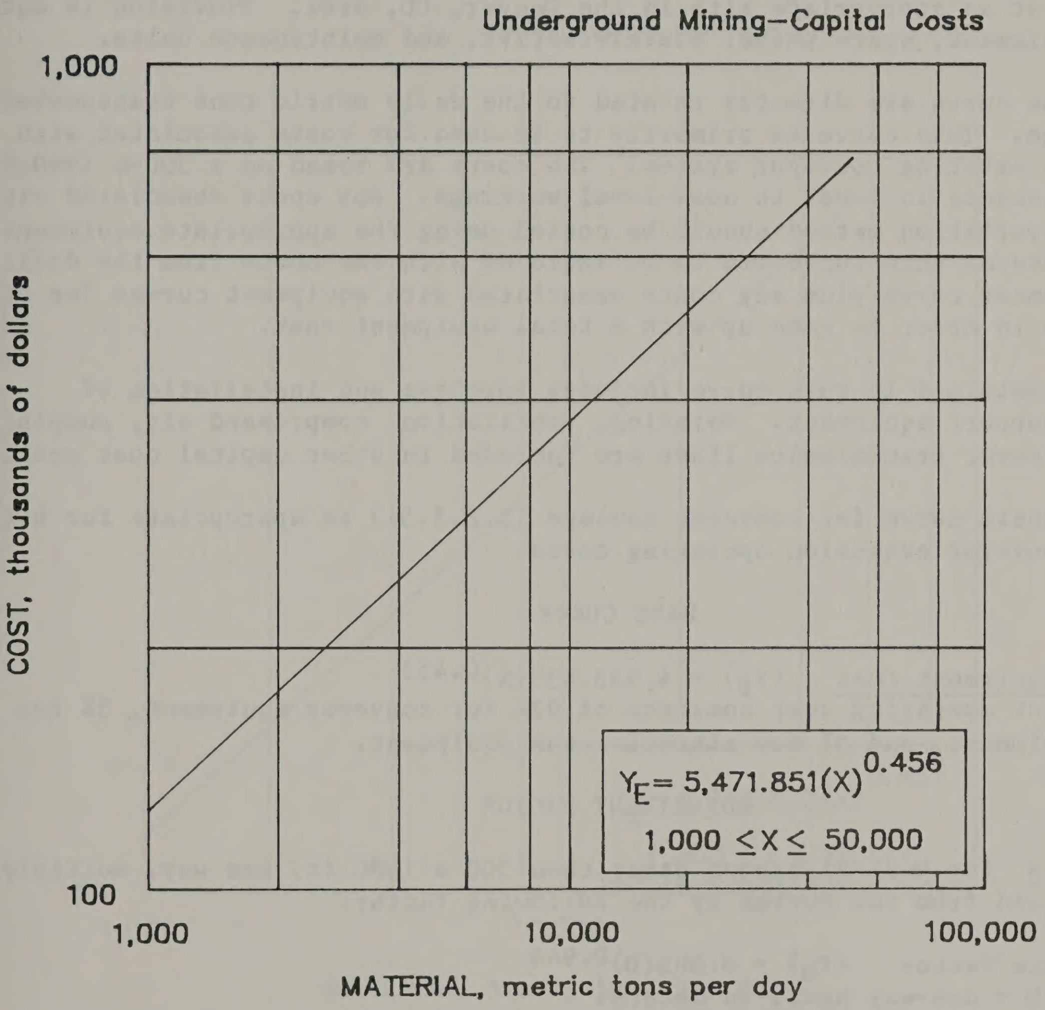
BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 5{,}471.851(X)^{0.456}$
The equipment operating cost consists of 92% for conveyor equipment, 3% for loading equipment, and 5% for miscellaneous equipment.

ADJUSTMENT FACTOR

Distance Factor For haul distances other than 300 m (980 ft) one way, multiply the costs obtained from the curves by the following factor:

Distance factor $(F_D) = 0.005(D)^{0.944}$
where D = one way haul, in meters.



4.2.3.5. Conveyor haulage equipment

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.6. CONVEYOR EXTENSIONS

The capital cost curve for conveyor extension equipment includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a transportation rate (X), in metric tons material per day. The curve is valid between 1,000 to 50,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

The costs on the curve are directly related to the daily metric tons transported by conveyor haulage. This curve is primarily to be used for costs associated with adding on to an existing conveyor system. The costs are based on a 300-m (980-ft) one-way haul distance in level to near-level workings. Any costs associated with a different transportation method should be costed using the appropriate equipment curve. The costs on this curve are to be included with the costs from the drill-and-blast equipment curve plus any costs associated with equipment curves for other haulage methods in order to come up with a total equipment cost.

The equipment contained in this curve includes purchase and installation of conveyors and support equipment. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

The operating costs curve for conveyor haulage (5.2.3.5.) is appropriate for both conveyor and conveyor extension operating costs.

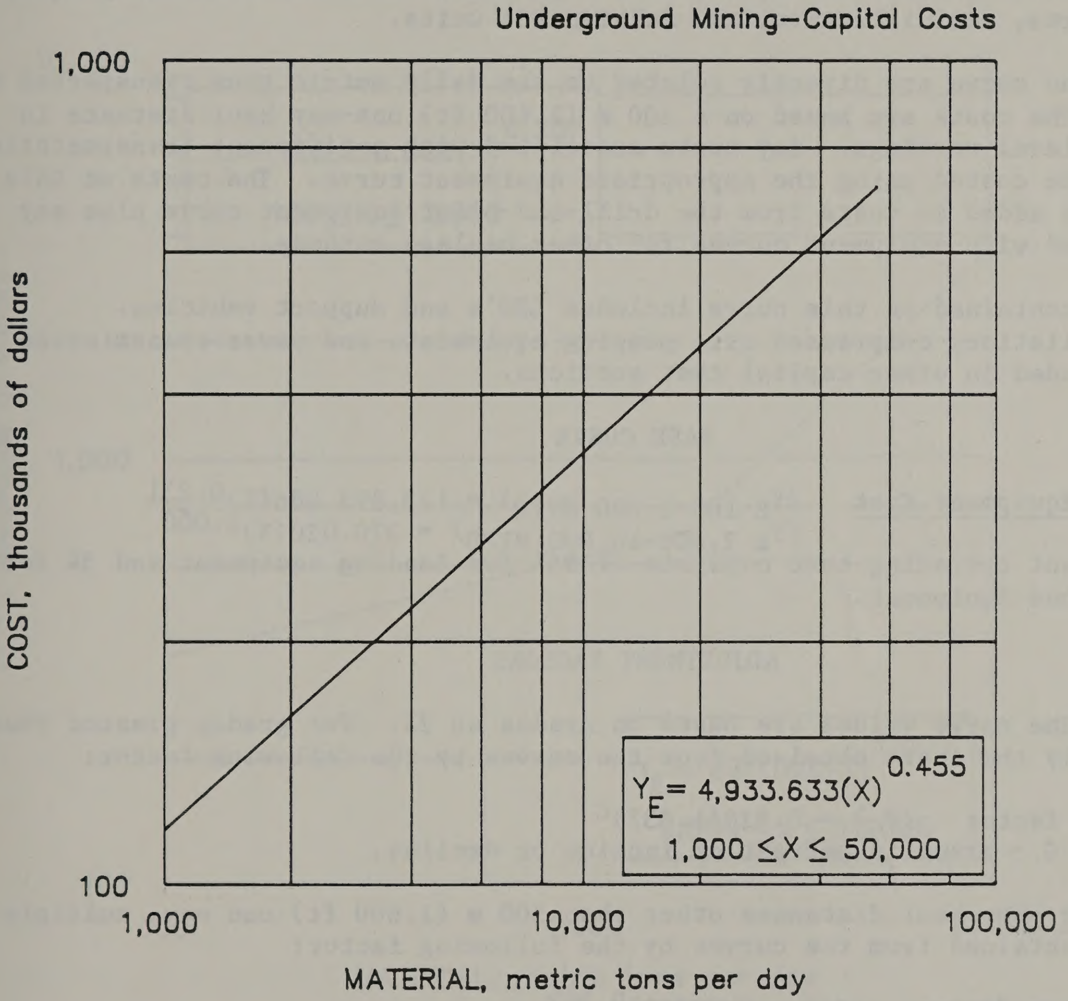
BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 4{,}933.633(X)^{0.455}$
The equipment operating cost consists of 92% for conveyor equipment, 3% for loading equipment, and 5% for miscellaneous equipment.

ADJUSTMENT FACTOR

Distance Factors For haul distances other than 300 m (980 ft) one way, multiply the costs obtained from the curves by the following factor:

Distance factor $(F_D) = 0.005(D)^{0.944}$
where D = one-way haul, in meters.



4.2.3.6. Conveyor extensions

4.2. UNDERGROUND MINING - CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.7. LOAD-HAUL-DUMP HAULAGE EQUIPMENT

The capital cost curve for LHD haulage includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a production range (X), in metric tons material per day. The curve is valid between 100 and 10,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

The costs on the curve are directly related to the daily metric tons transported by LHD haulage. The costs are based on a 500 m (1,600 ft) one-way haul distance in level to near-level workings. Any costs associated with a different transportation method should be costed using the appropriate equipment curve. The costs on this curve are to be added to costs from the drill-and-blast equipment curve plus any costs associated with equipment curves for other haulage methods.

The equipment contained in this curve includes LHD's and support vehicles. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E\ 100\text{-}2{,}000\ \text{MTPD}) = 123{,}893.086(X)^{0.231}$
$(Y_E\ 2{,}000\text{-}10{,}000\ \text{MTPD}) = 370.020(X)^{1.000}$

The equipment operating cost consists of 95% for loading equipment and 5% for miscellaneous equipment.

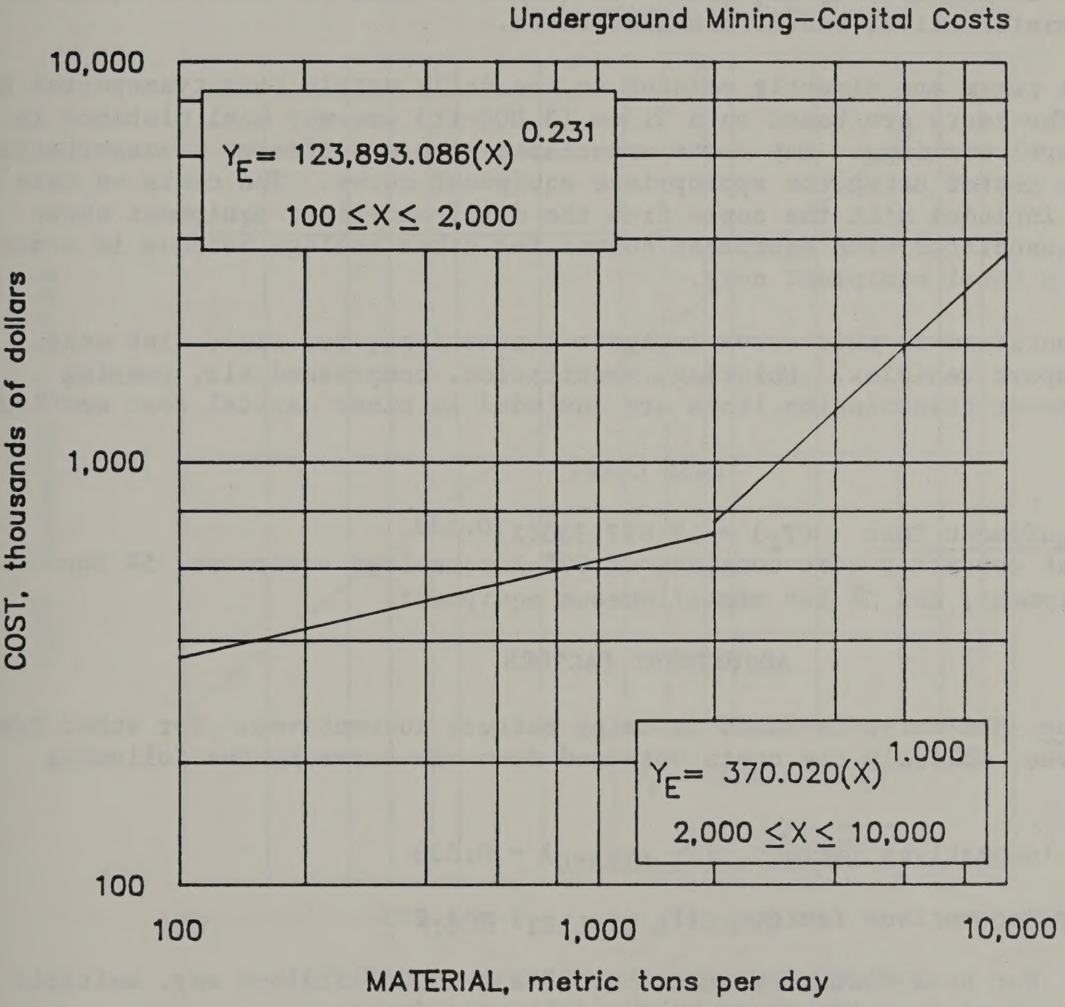
ADJUSTMENT FACTORS

Grade Factor The curve values are based on grades up 2%. For grades greater than 2%, multiply the costs obtained from the curves by the following factor:

Grade factor $(F_G) = 0.929(1.037)^G$
where G = grade in percent of incline or decline.

Distance Factor For haul distances other than 500 m (1,600 ft) one way, multiply the costs obtained from the curves by the following factor:

Distance factor $(F_D) = 0.098(D)^{0.382}$
where: D = one way haul, in meters.



4.2.3.7. L.H.D. haulage equipment

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.8. RAIL HAULAGE EQUIPMENT

The capital cost curve for rail haulage includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a tonnage transported (X), in metric tons per day. The curve is valid between 100 and 50,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for standby equipment, spare parts, administrative, and maintenance units.

The costs on the curve are directly related to the daily metric tons transported by rail haulage. The costs are based on a 915-m (3,000-ft) one-way haul distance in level to near-level workings. Any costs associated with a different transportation method should be costed using the appropriate equipment curve. The costs on this curve are to be included with the costs from the drill-and-blast equipment curve plus any costs associated with equipment curves for other haulage methods in order to come up with a total equipment cost.

The equipment contained in this curve includes locomotives, ore cars, flat cars, loaders, and support vehicles. Hoisting, ventilation, compressed air, pumping equipment, and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 19{,}697.330(X)^{0.539}$
The equipment operating cost consists of 90% for haulage equipment, 5% for loading equipment, and 5% for miscellaneous equipment.

ADJUSTMENT FACTORS

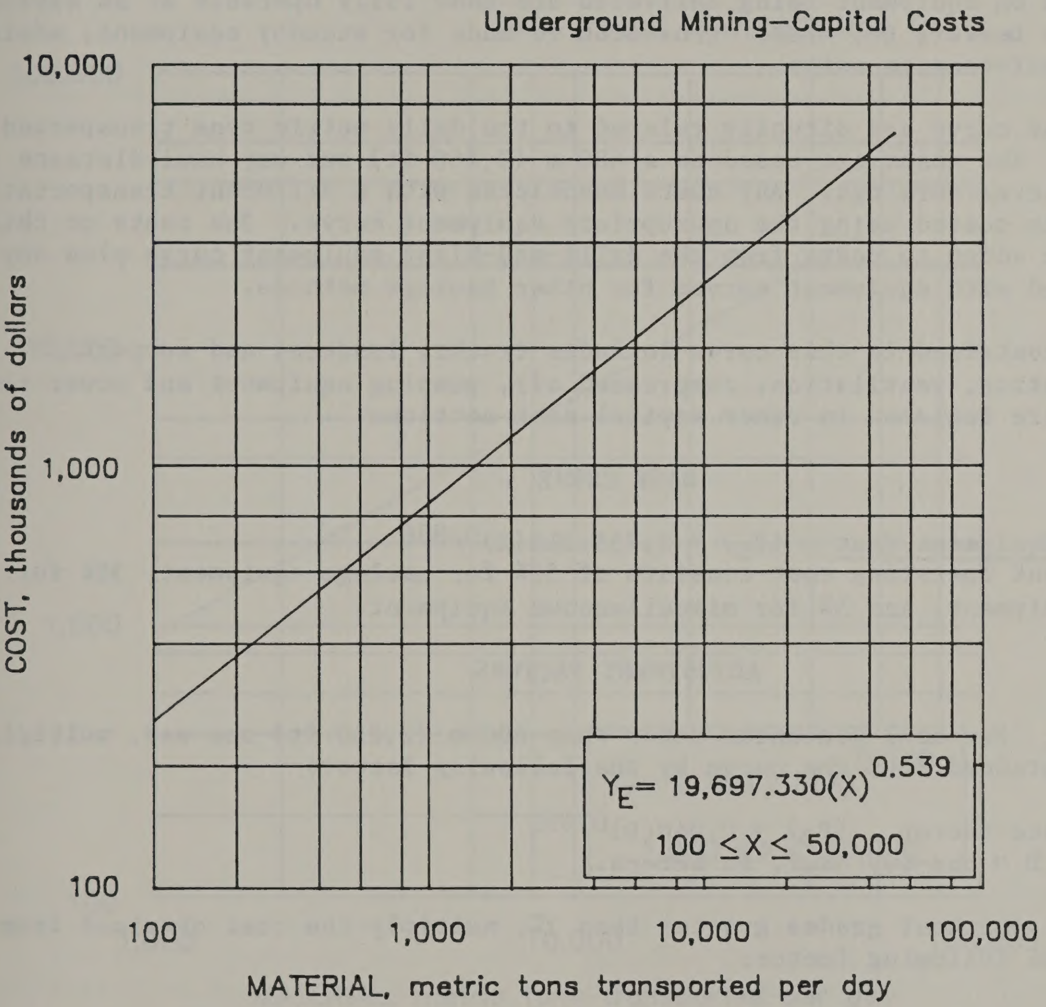
Locomotive Factor The curve is based on using battery locomotives. For other types of locomotives, multiply the costs obtained from the curve by the following factors:

Diesel locomotives factor $(F_{L\ DIESEL}) = 0.533$

Trolley locomotives factor $(F_{L\ TROLLEY}) = 1.273$

Distance Factor For haul distances other than 915 m (3,000 ft) one way, multiply the costs obtained from the curve by the following factor:

Distance Factor $(F_D) = 0.0013(D)^{0.968}$
where: D = one way haul, in meters.



4.2.3.8. Rail haulage equipment

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.3. MINING EQUIPMENT

4.2.3.9. TRUCK HAULAGE EQUIPMENT

The capital cost curve for truck haulage includes the purchase of underground equipment and items not previously included in other sections. The cost is based on the purchased equipment curve with a tonnage transported (X), in metric tons per day. The curve is valid between 1,000 and 50,000 mtpd, operating two shifts per day. These costs are based on equipment being delivered and made fully operable at an appropriate site in the Denver, CO, area. Provision is made for standby equipment, administrative, and maintenance units.

The costs on the curve are directly related to the daily metric tons transported by truck haulage. The costs are based on a 680-m (2,250-ft) one-way haul distance in level to near-level workings. Any costs associated with a different transportation method should be costed using the appropriate equipment curve. The costs on this curve are to be added to costs from the drill-and-blast equipment curve plus any costs associated with equipment curves for other haulage methods.

The equipment contained in this curve includes trucks, loaders, and support vehicles. Hoisting, ventilation, compressed air, pumping equipment and power transmission lines are included in other capital cost sections.

BASE CURVE

(E) Purchased Equipment Cost $(Y_E) = 2,759.215(X)^{0.838}$
The equipment operating cost consists of 57% for haulage equipment, 38% for loading equipment, and 5% for miscellaneous equipment.

ADJUSTMENT FACTORS

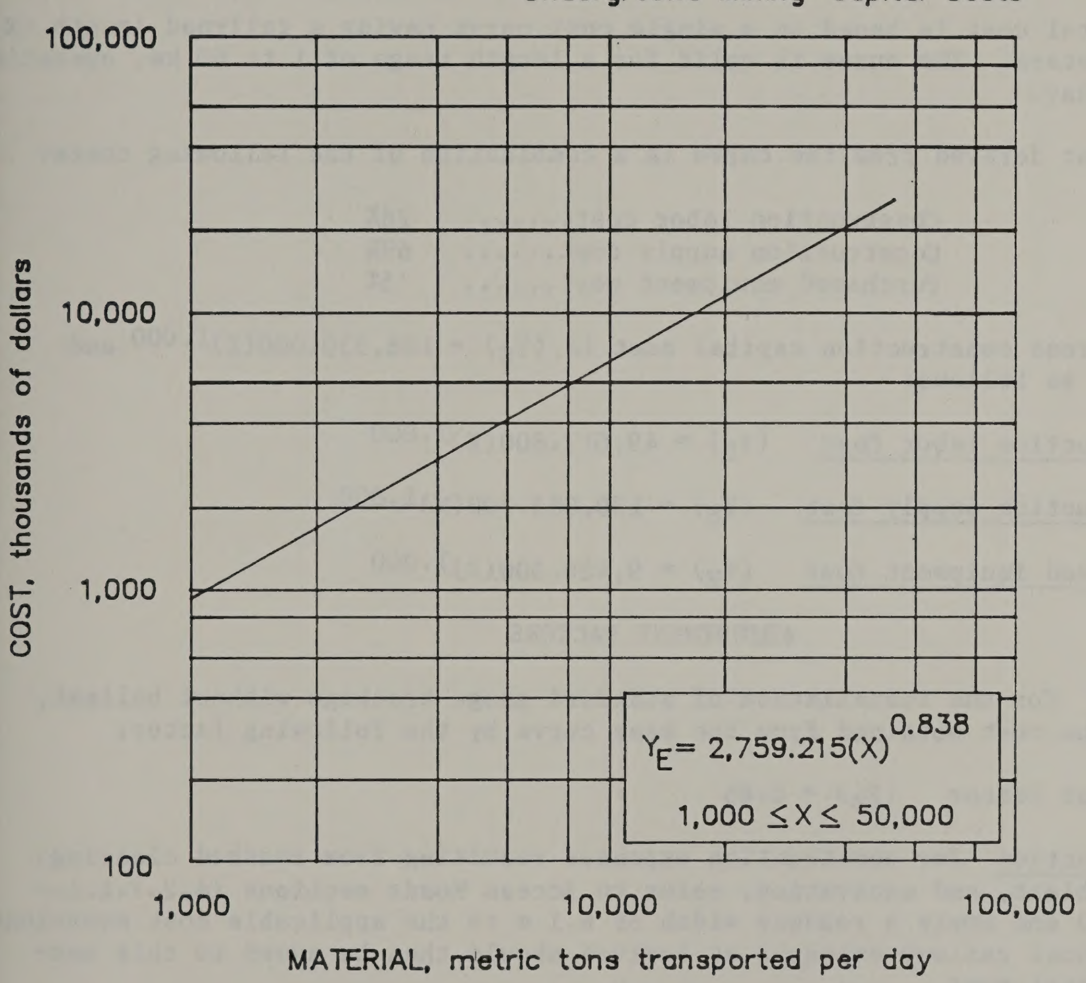
Distance Factor For haul distances other than 680 m (2,250 ft) one way, multiply the cost obtained from the curve by the following factor:

Distance factor $(F_D) = 0.040(D)^{0.492}$
where D = one-way haul, in meters.

Incline Factor For haul grades greater than 2%, multiply the cost obtained from the curve by the following factor:

Incline factor $(F_I) = 1.0 + 0.016(G)$
where: G = grade, in degrees.

Underground Mining—Capital Costs



4.2.3.9. Truck haulage equipment

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.4. TRANSPORTATION

4.2.4.4. RAILROAD CONSTRUCTION

The cost in this section covers the capital expense for laying standard-gage trackage for main lines and spurs. The cost reflects railway installation by a crew that works on a one-shift-per-day schedule; furthermore, the cost is based on trackage that is fully ballasted.

BASE CURVE

The total capital cost is based on a single cost curve having a railroad length (X), in total kilometers. The curve is valid for a length range of 1 to 60 km, operating one shift per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	26%
Construction supply cost......	69%
Purchased equipment cost......	5%

The total railroad construction capital cost is $(Y_C) = 188{,}530.000(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 49{,}017.800(X)^{1.000}$

(S) Construction Supply Cost $(Y_S) = 130{,}085.700(X)^{1.000}$

(E) Purchased Equipment Cost $(Y_E) = 9{,}426.500(X)^{1.000}$

ADJUSTMENT FACTORS

Ballast Factor For the installation of standard-gauge trackage without ballast, multiply the cost obtained from the base curve by the following factor:

Ballast factor $(F_B) = 0.85$

Roadbed Construction For construction expenses resulting from roadbed clearing, drill and blast, and excavation, refer to Access Roads sections (4.2.7.1.1.-4.2.7.1.3.) and apply a roadway width of 6.1 m to the applicable cost equations; the additional railway expenses so derived should then be added to this section's capital cost.

Equipment Factor When it is necessary to purchase equipment or to have a subcontractor perform the work, multiply the equipment operation value by the following factor in order to obtain the total value of equipment expense for ownership and operation:

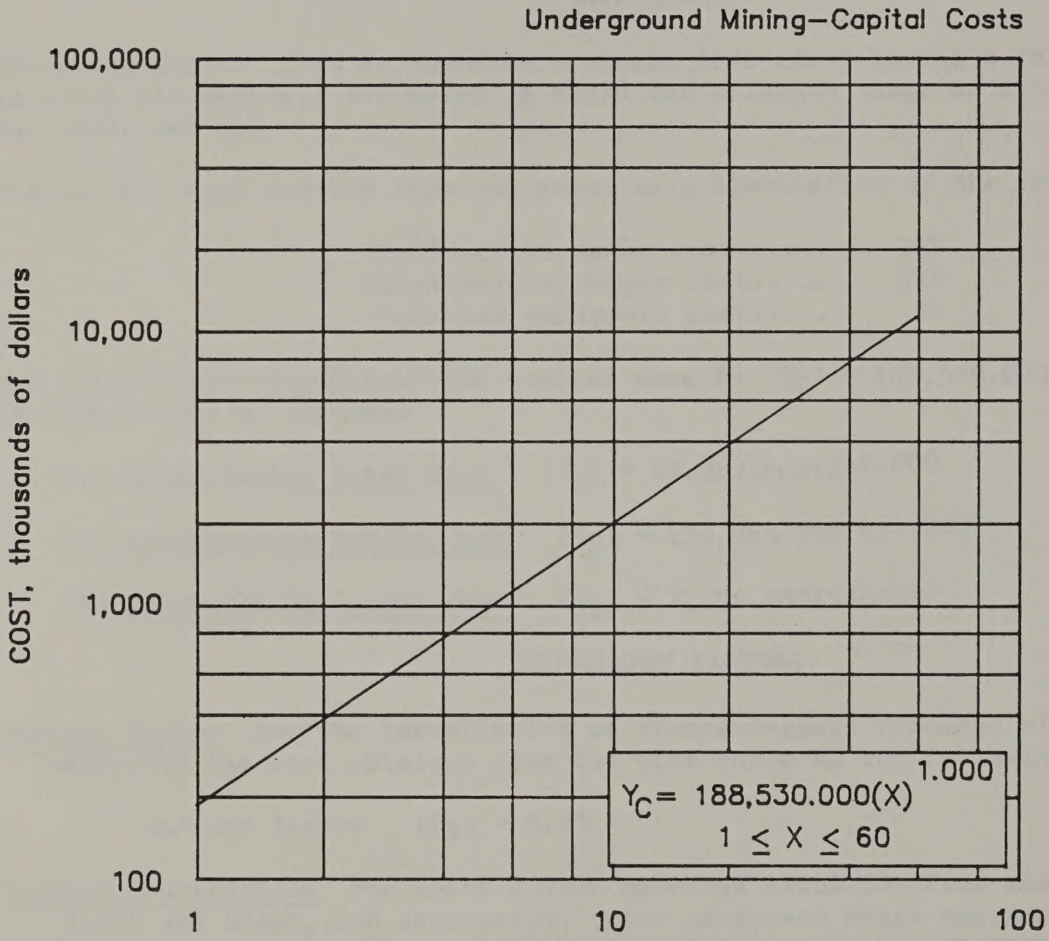
Equipment operation factor $(Y_E) = 1.7$

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(Y_L) = 1.5$

Supply factor $(Y_S) = 1.2$

Equipment operation factor $(Y_E) = 1.2$



4.2.4.4. Railroad construction

4.2.4.5. LONG-DISTANCE SURFACE CONVEYOR

The cost curve shown is for the acquisition and erection of a long-distance surface conveyor. The conveyor is a single-flight belt conveyor made with high-strength steel belting. The conveyor is designed for a 10° slope and 1-km distance. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher capital costs are not included in this cost but are covered in separate sections.

BASE CURVE

The total cost is based on a single cost curve having a production rate (X), in metric tons material per day. The curve is valid for production rates of 15,000 to 150,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, installation of the belt, idlers, motors, channel, and frame, and site preparation.

The long distance surface conveyor capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	31%
Construction supply cost......	5%
Purchased equipment cost......	64%

A typical breakdown of a long distance surface conveyor major cost components is:

Conveyor belt......................	36%
Idler assembly units...............	44%
Motors, drive trains, belt cleaners, and other mechanical items.........	20%

The total long distance surface conveyor capital cost is $(Y_C) = 81{,}292.281(X)^{0.309}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 25{,}200.607(X)^{0.309}$

(S) Construction Supply Cost $(Y_S) = 4{,}064.614(X)^{0.309}$

(E) Purchased Equipment Cost $(Y_E) = 52{,}027.060(X)^{0.309}$

ADJUSTMENT FACTORS

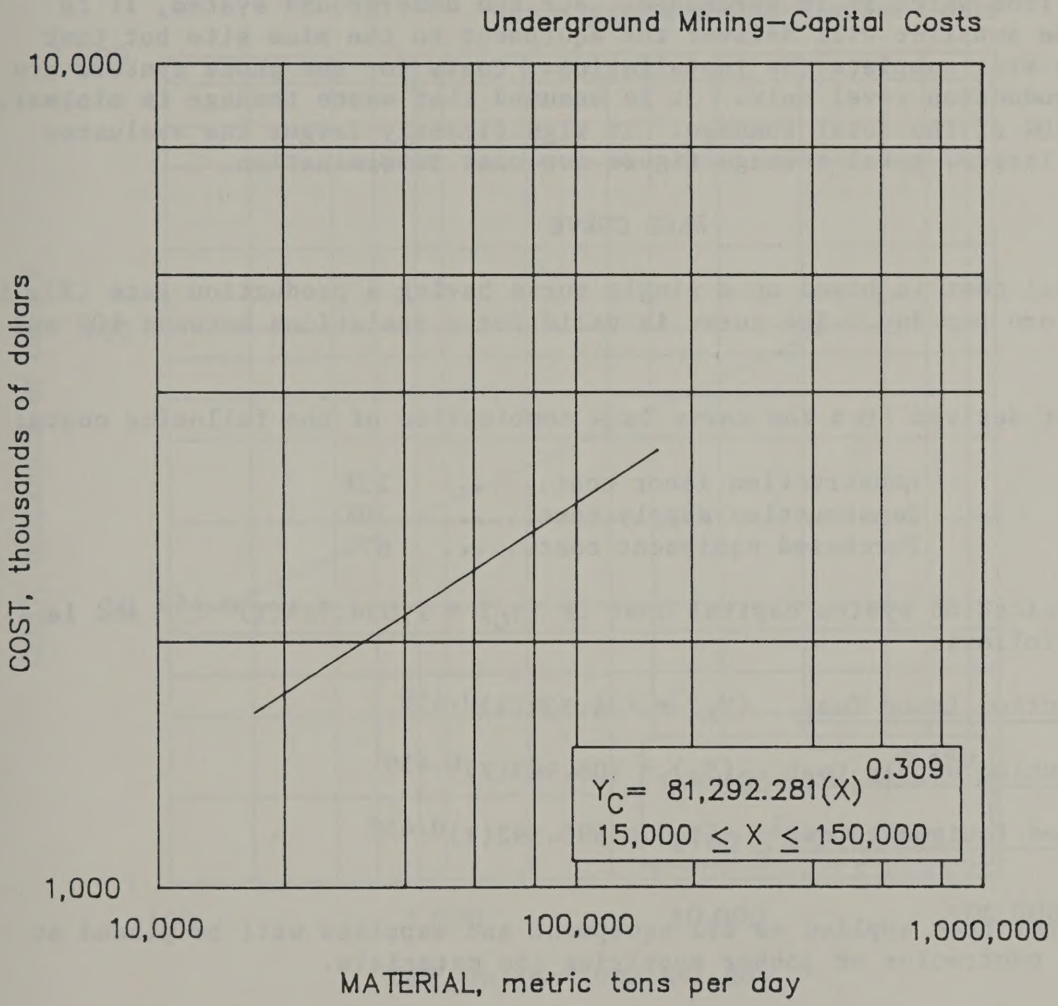
Belt Life The conveyor belt, 36% of equipment cost, has an average wear life of 8 to 10 yr of use, based on three shifts per day, 350 operating days per year, and depending on the abrasiveness of the material. The total replacement of the belt is standard procedure after excessive wear.

Conveyor Length and Slope Factor The conveyor is 1-km long and has a 10^{o} slope. For other lengths and slopes, multiply the cost obtained from the base curve by the following factor:

Conveyor length and slope factor $(F_L) = [0.917+0.00940(S)][L/1]$
where: L = length, in kilometers,
and S = slope in degrees, between 0^{o} and 15^{o}.

The cost for a decline conveyor is equal to that for a horizontal conveyor (0^{o} slope).

Stacker-Tripper Factor If the material is conveyed to a processing plant or other end point such as a port facility, the capital cost for unloading from the conveyor is included in those sections. If the material is waste rock, then the cost for a tripper or stacker should be added to the estimated capital cost. Costs for these items vary greatly but can range from $600,000 for a stacker or tripper that handles 15,000 mtpd waste material to $5,000,000 for a stacker or tripper that handles 150,000 mtpd of waste rock.



4.2.4.5. Long distance surface conveyor

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.1. COMMUNICATIONS SYSTEM

Costs in this section cover the purchase and installation of complete surface and underground communications systems. Included are extension lines from existing system networks; surface facilities, phone and paging systems; and underground lines and audible phone paging stations. Because of the current structure of the communications industry it is likely that all surface lines and equipment will be installed by the company from which it is purchased. For the underground system, it is assumed that the supplier will deliver the equipment to the mine site but that operating labor will complete the installation. Costs for the phone systems are based on ore production level only. It is assumed that waste tonnage is minimal, approximately 10% of the total tonnage. If significantly larger the evaluator should use the larger, total tonnage figure for cost determination.

BASE CURVE

The total capital cost is based on a single curve having a production rate (X), in metric tons of ore per day. The curve is valid for a operations between 100 and 50,000 mtpd.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	13%
Construction supply cost......	20%
Purchased equipment cost......	67%

The total communication system capital cost is $(Y_C) = 1{,}034.914(X)^{0.459}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 134.539(X)^{0.459}$

(S) Construction Supply Cost $(Y_S) = 206.983(X)^{0.459}$

(E) Purchased Equipment Cost[1] $(Y_E) = 693.392(X)^{0.459}$

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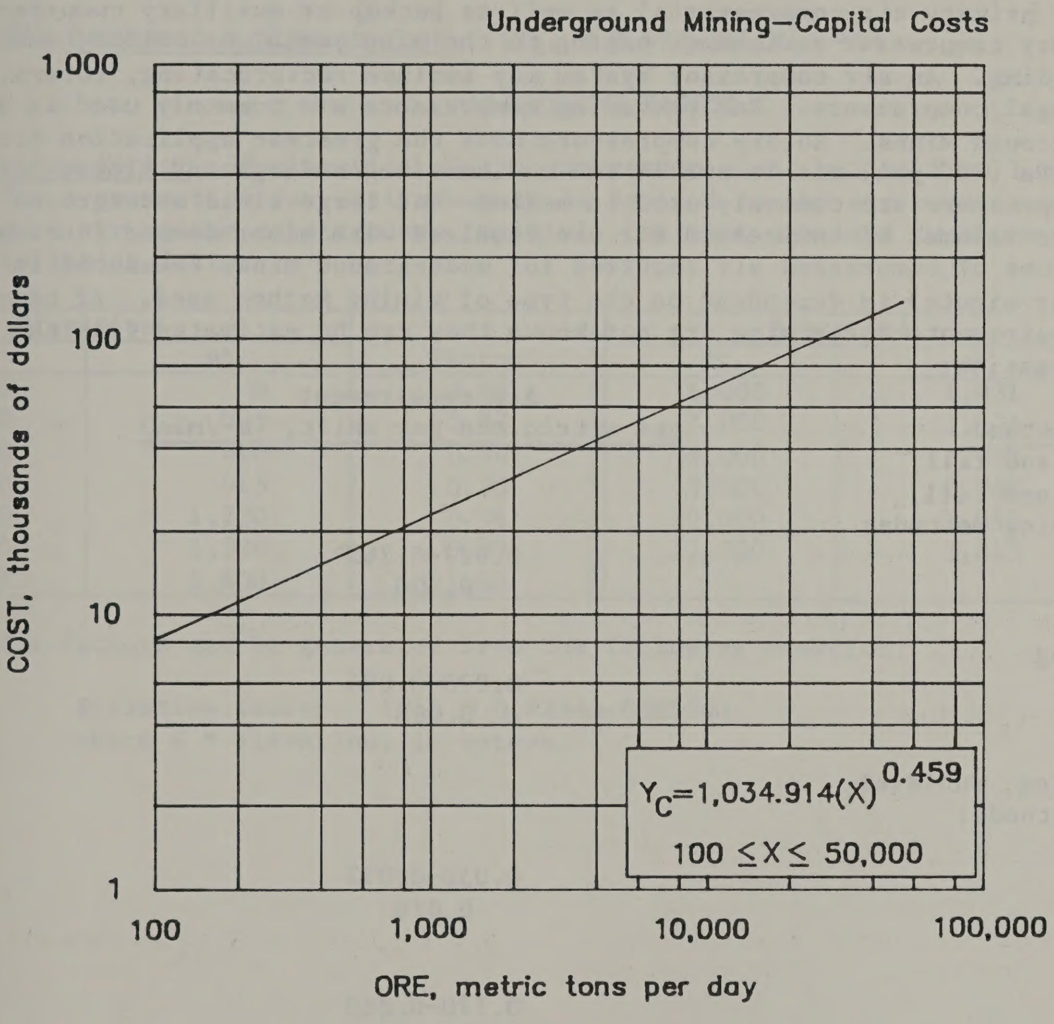
[1] Freight has not been applied as all equipment and supplies will be placed at the site by the contractor or jobber supplying the materials.



4.2.5.1. Communications system

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.2. COMPRESSED AIR FACILITIES

Capital costs for compressed air system, as presented here, are based on capacity of the facilities. This section will deal with compressors having an atmospheric pressure intake and a discharge pressure of 689 to 861 kPa (100 to 125 psi). Higher pressure compressor systems (1724 to 2413 kPa) are accounted for in the appropriate mining methods sections (vertical crater retreat and blasthole). A compressed air system includes primary air compressor(s) as well as backup or auxillary compressor(s), ancillary compressor equipment, piping to the mine portal or collar, and a compressor building. An air compressor system may include reciprocating, rotary, and/or centrifugal compressors. Reciprocating compressors are commonly used in all sizes of underground mines. Rotary compressors have the greatest application for supplying 689 kPa (100 psi) air to small- and medium-sized underground mines. Centrifugal compressors are commonly used in medium- and large-sized underground mines when large volumes of compressed air are required with minor demand fluctuations. The volume of compressed air required for underground mines (measured in cubic meters per minute) is dependent on the type of mining method used. If compressed air requirements for a mine are not known they can be estimated from the following information:

Mining Method	Air requirement per metric ton per shift, (m^3/min)
Shrinkage, cut and fill, mechanized cut and fill, square-set stoping methods:	
Range	0.027-0.265
Average	0.200
Blasthole mining:	
Range	0.073-0.094
Average	0.083
Longhole drilling, sublevel, block caving methods:	
Range	0.050-0.093
Average	0.070
Open stoping:	
Range	0.170-0.260
Average	0.200

BASE CURVE

Total cost is based on a single cost curve having a total compressor capacity (X), in cubic meters installed capacity per minute, which includes line losses, leaks, and drilling diversity for a plant installed at 1,600 m (5,249 ft) elevation. The curve is valid for capacities between 20 and 2,000 m^3/min.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	7%
Construction supply cost......	5%
Purchased equipment cost......	88%

The total compressed air facilities capital cost is $(Y_C) = 9{,}884.496(X)^{0.695}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 691.915(X)^{0.695}$

(S) Construction Supply Cost $(Y_S) = 494.225(X)^{0.695}$

(E) Purchased Equipment Cost $(Y_E) = 8{,}698.356(X)^{0.695}$

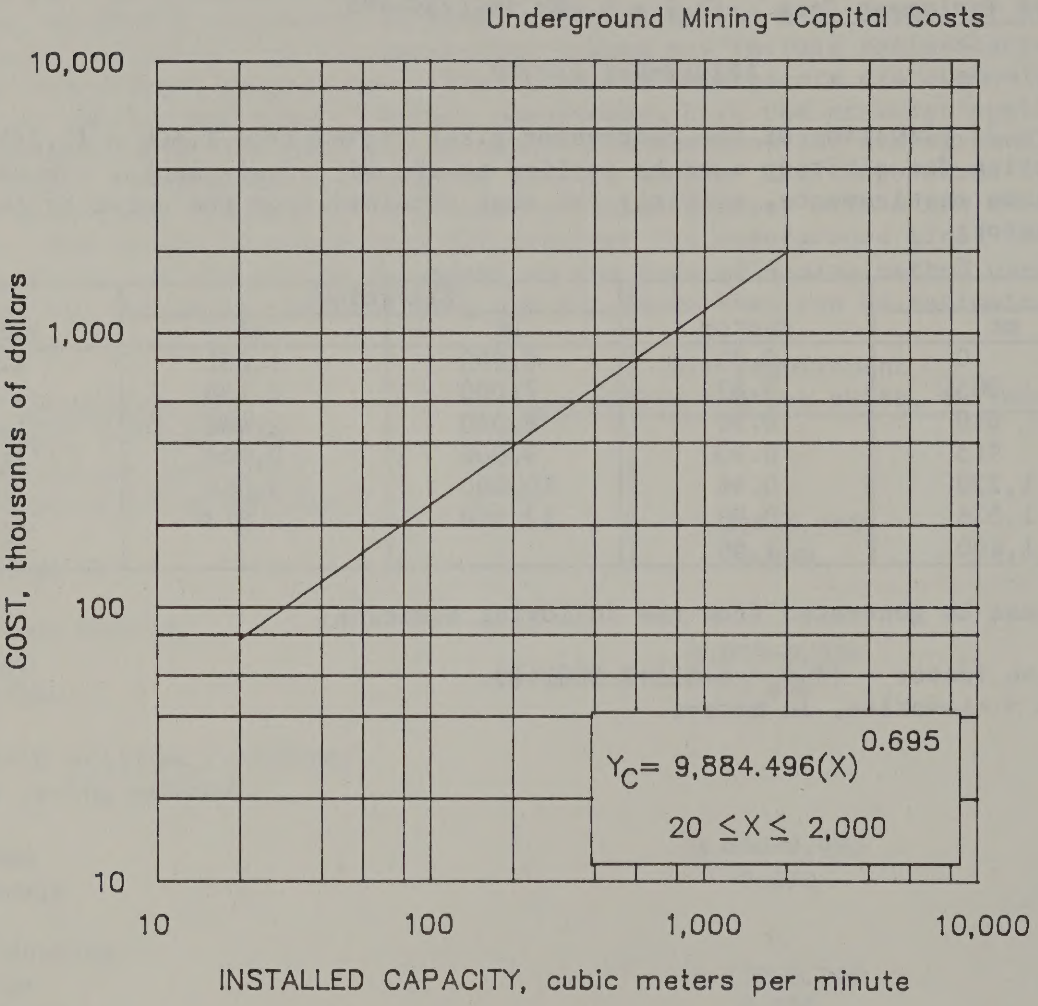
ADJUSTMENT FACTOR

Elevation Factor If elevation of the compressor plant varies from 1,600 m (5,249 ft) a correction for altitude must be applied to the air requirements. To adjust air volume requirements, multiply the cost obtained from the curve by the following factor:

Elevation,		Factor	Elevation,		Factor
ft	mt		ft	mt	
0	0	0.85	6,000	1,831	1.03
1,000	305	0.87	7,000	2,136	1.07
2,000	610	0.90	8,000	2,441	1.11
3,000	915	0.93	9,000	2,746	1.15
4,000	1,220	0.96	10,000	3,050	1.19
5,000	1,526	0.99	12,500	3,813	1.31
5,249	1,600	1.00			

The factors can be generated from the following equation:

Elevation factor $(F_E) = 0.823+0.0001(G)$
where G = elevation, in meters.



4.2.5.2. Compressed air facilities

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.3. ELECTRICAL SYSTEM

Costs derived from this section include the purchase and installation of all electrical devices as well as lines and poles to service all surface and underground facilities. Power is carried to the servicing transformer at each building or load location. This includes all distribution lines on the surface, the major distribution lines down the shaft, and subfeeders to the load locations throughout the mine.

Two methods of cost determination are presented:

1) Determine standardized power requirements from the equations given below and using this value, determine the electrical system capital cost by referring to the base curve or the related equation.

Tonnage/electrical consumption equations:

$\text{Total kW} = 46.61(T)^{0.640}$
where: T = ore and waste mined, in metric tons per day.

2) Determine the electrical consumption rate for the mine under study through review of the motor and lighting requirements, and use this total value rather than standardized power requirements for cost determination using the base curve.

BASE CURVE

The total cost is based on a single curve having power requirements (X), in total kilowatts. The curve is valid for operations between 1,000 and 40,000 kW, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	67%
Construction supply cost......	12%
Purchased equipment cost......	21%

The total electrical system capital cost is $(Y_C) = 934.503(X)^{0.720}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 626.117(X)^{0.720}$

(S) Construction Supply Cost $(Y_S) = 112.140(X)^{0.720}$

(E) Purchased Equipment Cost $(Y_E) = 196.246(X)^{0.720}$

ADJUSTMENT FACTORS

Substation Factor In many cases, power companies are able to supply power directly and a substation is not required; or, if it is required, the power company is willing to absorb the cost of its installation. This is especially true for the smaller tonnage facilities whose power usage does not exceed 10,000 kV·A. To adjust the electrical system capital costs for these instances, multiply the costs obtained from the curves by the following factors:

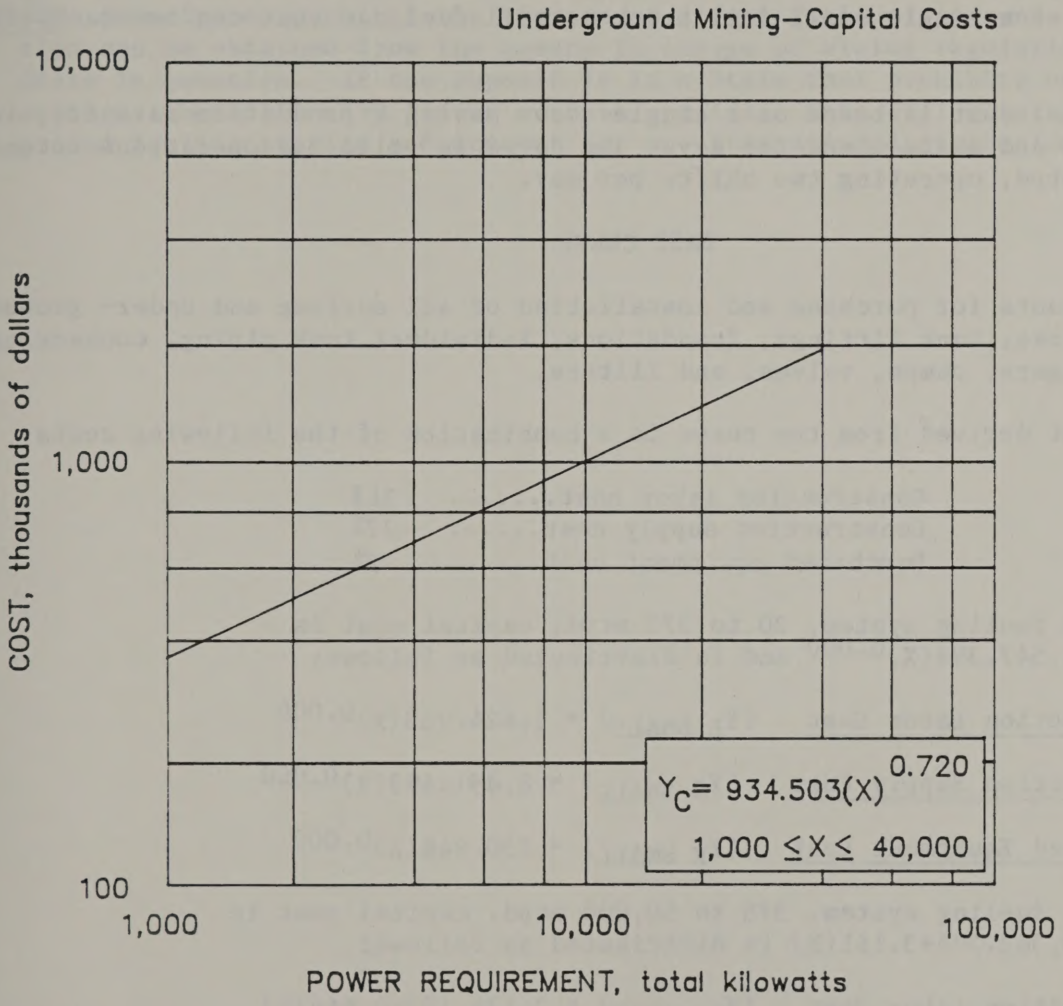
Labor factor $(F_L) = 0.93$

Supply factor $(F_S) = 0.98$

Purchased equipment factor $(F_E) = 0.53$

Adit Entry Factor In the event an adit entry is the primary means of access for the mine under investigation it is necessary to reduce the total kilowatt demand by the power requirements for hoisting and drainage. As both of these activities will not be required in that instance, reduce the total power appropriately before determining the capital cost using the cost equation contained in this section. If the evaluator has estimated or knows the power requirements for these activities, the adjustment can be made directly. If the power requirements are being estimated using the metric tons mined to kilowatt demand equation on the previous page, multiply the costs obtained from the curves by the following factor:

Adit entry factor $(F_A) = 0.47$



4.2.5.3. Electrical system

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.4. FUELING SYSTEM

The capital cost of fueling systems is based on estimated daily mine production, and accounts for all supplies and equipment needed for fuel storage and distribution, as well as installation labor. Costs are based on shaft entry mines serviced primarily by diesel equipment. Factors are provided for nondiesel operations, and mines accessed by adits. Mines generally have large surface fuel storage facilities that are connected by feeder lines to small underground distribution tanks. Small operations may rely on a single small fuel truck or rail fuel car that can be transported between levels.

The total capital cost is based on a single curve having a production rate (X), in metric tons ore and waste mined per day. The curve is valid for operations between 20 and 50,000 mtpd, operating two shifts per day.

BASE CURVE

Total cost accounts for purchase and installation of all surface and under- ground fuel storage tanks, tank fittings, foundations, individual tank piping, connecting pipes, pipe hangers, pumps, valves, and filters.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	21%
Construction supply cost......	77%
Purchased equipment cost......	2%

The total small fueling system, 20 to 375 mtpd, capital cost is $(Y_{C\ SMALL}) = 11{,}547.394(X)^{0.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 2{,}424.953(X)^{0.000}$

(S) Construction Supply Cost $(Y_{S\ SMALL}) = 8{,}891.493(X)^{0.000}$

(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 230.948(X)^{0.000}$

The total large fueling system, 375 to 50,000 mtpd, capital cost is $(Y_{C\ LARGE}) = 10{,}362.394+3.161(X)$ is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 2{,}176.103+0.664(X)$

(S) Construction Supply Cost $(Y_{S\ LARGE}) = 7{,}979.043+2.434(X)$

(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 207.248+0.063(X)$

ADJUSTMENT FACTORS

Nondiesel Mine Factor In mines where the majority of the equipment is powered by sources other than diesel fuel, only a small surface storage facility is needed.

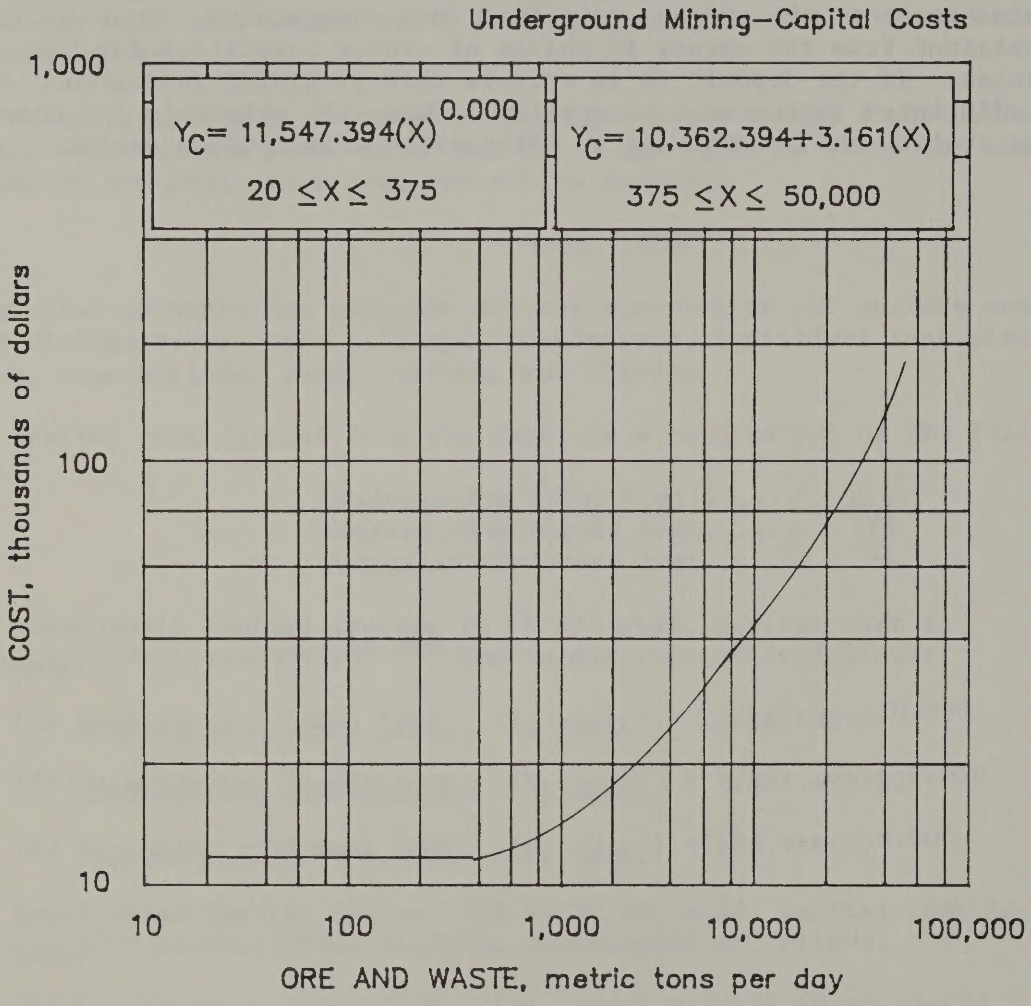
To account for this reduction in equipment, multiply the cost obtained from the curve by the following factor:

Nondiesel mine factor $(F_N) = 0.148$

Adit Entry Factor Mines that use an adit as their main access often depend on fuel trucks for diesel distribution rather than an underground fuel tank and pumping station. To account for the elimination of the underground fueling station, and the addition of a fuel truck, multiply the cost obtained from the curve by the following factor:

Adit entry factor $(F_A) = 0.854$

CAUTION Some States prohibit the storage of diesel fuel underground. This information can be obtained from the agency in charge of mining regulation for the State in question. If the deposit is in a State that prohibits underground fuel storage, the adit entry factor must be applied. This will eliminate the underground fueling station and account for an alternative distribution system.



4.2.5.4. Fueling system

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.6. OFFICES AND LABORATORIES

The cost curves for offices and laboratories include construction of general offices, engineering and safety offices, and laboratories, including furnishings as well as all necessary assay equipment. Building costs are based on masonry construction. In this section, office and laboratory capital costs are presented separately. It has been found that the type of equipment required as well as typical construction of these two facilities differ considerably; therefore, separate curves allow for greater accuracy in cost determination for these categories. To determine the total cost for this section it is necessary to determine each category cost individually and then combine the resultant two values.

BASE CURVES

The costs obtained from these curves are based on the assumption that these facilities will be used only for mining operations. If the mine and mineral processing plant are to share the same facilities, the user must determine, using a knowledge of the requirements, what can be jointly used and apportion the resulting costs to the mine and plant.

OFFICES

The total capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons ore and waste mined per day (a typical waste tonnage of 10% is assumed; if this percentage is substantially exceeded, the total tonnage should be used for T). The curve is valid for areas of 60 to 4,000 m^2, or 150 to 22,000 mtpd, operating two mining shifts per day. The capital cost curve for offices includes construction of administrative, engineering, and safety office space, as well as office furnishings.

If office space requirements are known the capital cost estimate may be made directly by consulting the curve; if space requirements are not known they can be estimated from the following equation:

Square meters of office space = $4.332(T)^{0.588}$
where: T = ore and waste mined, in metric tons per day.

The final cost office cost derived from the curve is a combination of the following costs:

Construction labor cost.......	39%
Construction supply cost......	50%
Purchased equipment cost......	11%

The total office capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 812.061(X)^{0.965}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{OFFICES\text{-}SQ\ M}}) = 316.704(X)^{0.965}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{OFFICES\text{-}SQ\ M}}) = 406.031(X)^{0.965}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{OFFICES\text{-}SQ\ M}}) = 89.327(X)^{0.965}$

The total office capital cost is $(Y_{C\ \mathrm{MTPD}}) = 2{,}961.959(T)^{0.595}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{OFFICES\text{-}MTPD}}) = 1{,}155.164(T)^{0.595}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{OFFICES\text{-}MTPD}}) = 1{,}480.980(T)^{0.595}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{OFFICES\text{-}MTPD}}) = 325.815(T)^{0.595}$

LABORATORIES

The total capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons ore and waste mined per day (a typical waste tonnage of 10% is assumed; if this percentage is substantially exceeded, the total tonnage should be used for T). The curve is valid for areas of 28 to 700 m², or 850 to 18,000 mtpd, operating two mining shifts per day. The capital cost curve for assay laboratories includes construction of sample preparation, analytical, and metallurgical laboratory space as well as crushing, assaying, and metallurgical laboratory equipment. The capital cost is based on steel building construction and is for a laboratory used only by the mine. If laboratory space requirements are not known they can be estimated from the following equation:

Square meters of laboratory space = $0.687(T)^{0.628}$
where: T = ore and waste mined, in metric tons per day.

Use the larger of 28 m² or the computed value for actual cost determination through the base curve below if laboratory facilities are to be built on-site.

The final assay laboratory cost derived from the curve is a combination of the following costs:

Construction labor cost.......	20%
Construction supply cost......	22%
Purchased equipment cost......	58%

The total laboratory capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 2{,}645.438(X)^{0.901}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{LABS\text{-}SQ\ M}}) = 529.088(X)^{0.901}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{LABS\text{-}SQ\ M}}) = 581.996(X)^{0.901}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{LABS\text{-}SQ\ M}}) = 1534.354(X)^{0.901}$

The total laboratory capital cost is $(Y_{C\ MTPD}) = 1{,}874.219(T)^{0.565}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS\text{-}MTPD}) = 374.844(T)^{0.565}$

(S) Construction Supply Cost $(Y_{S\ LABS\text{-}MTPD}) = 412.328(T)^{0.565}$

(E) Purchased Equipment Cost $(Y_{E\ LABS\text{-}MTPD}) = 1{,}087.047(T)^{0.565}$

ADJUSTMENT FACTORS

Joint Facility Factor When laboratory facilities are jointly used, which is often the case, multiply the laboratory area requirements for the mine by 1.5, determine the appropriate capital cost, and then split the cost 50% for the mine and mill capital cost categories. Combined mine and mill laboratory area should not exceed 700 m^2. If the number of samples assayed by the mine and mill are known, laboratory cost should be divided on this basis.

Shift Factor It is important to note that if a smaller laboratory is built with the intent of operating three shifts per day rather than two, as assumed for the base case, capital costs will be substantially reduced. Likewise, space requirements for a laboratory operated one shift per day will be considerably greater. To adjust from the two shift basis it is necessary to multiply the shift ratio (base/actual) times the mine capacity before determining the space requirements through the tonnage/square meter relationship and then use the adjusted value for actual cost determination. For offices this is not generally considered to be a suitable adjustment as these facilities are invariably used only one shift per day.

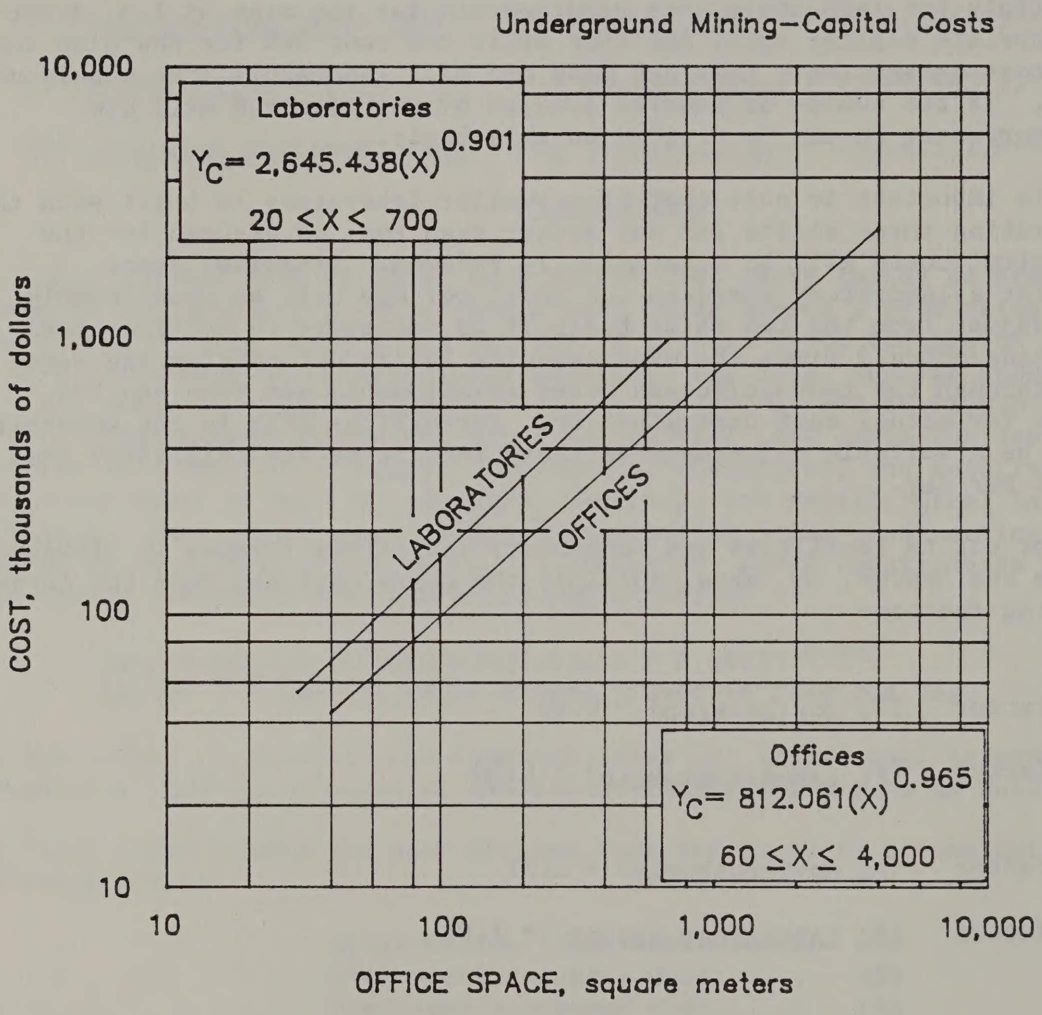
Weather Factor For office facilities and laboratory facilities located in climates that vary from the Denver, CO, area, multiply the costs obtained from the curves by the following factors:

Mild areas:
Weather factor $(F_{L\ OFFICE\text{-}MILD}) = 0.95$

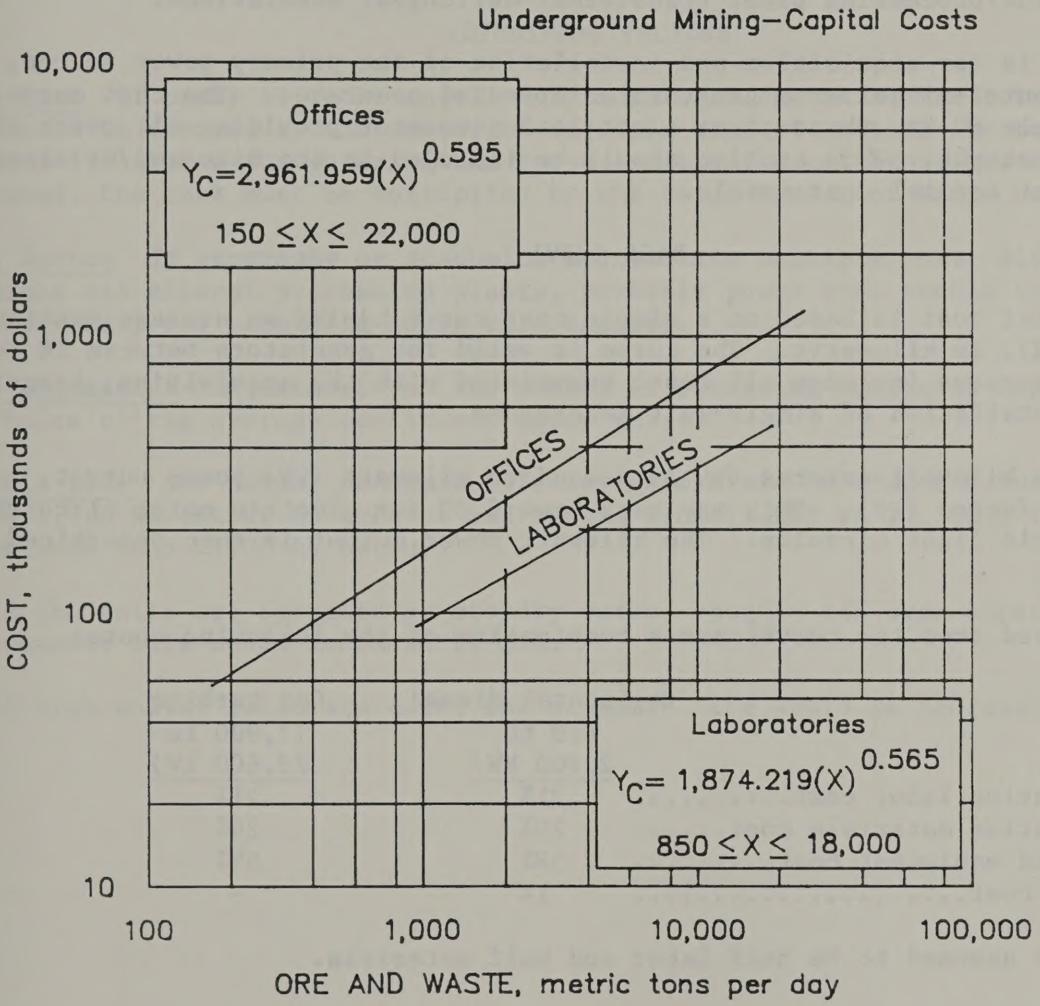
Weather factor $(F_{L\ LABORATORY\text{-}MILD}) = 0.98$

Severe areas:
Weather factor $(F_{L\ OFFICE\text{-}SEVERE}) = 1.07$

Weather factor $(F_{L\ LABORATORY\text{-}SEVERE}) = 1.04$



4.2.5.6.a Offices and laboratories



4.2.5.6.b Offices and laboratories

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.7. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 5.2.4.8. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. No adjustments are necessary for the mine or mineral processing plant electrical system [sections 2.2.4.2., 4.2.5.3., and 6.1.8.4. (IC 9143)] because output power matches the power input to the mine/processing plant transformer-switchgear substations.

The cost shown is for acquisition and installation of the primary power source, either a horizontal-diesel or a gas-turbine operated generator. The cost curve is based on a single 60-Hz, three-phase electrical generator providing all power at the rated kilowatt output. This section should be included in the mine and/or mineral processing plant capital cost totals.

BASE CURVE

The total capital cost is based on a single cost curve having an average continuous power output (X), in kilowatts. The curve is valid for generators between 18 to 23,600 kW. The curve includes all costs associated with the acquisition, transportation, and installation of single-unit generators.

To convert from kilovolt amperes (kV•A) demand to kilowatt (kW) power output, estimate power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt power output is then determined by kV•A x PF = kW.

The costs derived from the curves are a combination of the following costs:

	Horizontal diesel (18 to 2,900 kW)	Gas turbine (2,900 to 23,600 kW)
Installation labor cost..........	21%	21%
Installation materials cost......	20%	20%
Purchased equipment cost.........	58%	59%
Freight cost.....................	1%	-

Installation is assumed to be half labor and half materials.

The total diesel powered portable power generation capital cost is $(Y_{C\ DIESEL}) = 797.574(X)^{0.876}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ DIESEL}) = 167.491(X)^{0.876}$

(S) Installation Materials Cost $(Y_{S\ DIESEL}) = 159.514(X)^{0.876}$

(E) Purchased Equipment Cost $(Y_{E\ DIESEL}) = 470.568(X)^{0.876}$

The total turbine-powered portable power generation capital cost is ($Y_{C\ TURBINE}$) = $2{,}251.219(X)^{0.872}$ and is distributed as follows:

(L) Installation Labor Cost ($Y_{L\ TURBINE}$) = $472.756(X)^{0.872}$

(S) Installation Materials Cost ($Y_{S\ TURBINE}$) = $450.244(X)^{0.872}$

(E) Purchased Equipment Cost ($Y_{E\ TURBINE}$) = $1328.219(X)^{0.872}$

Power Output Determination For surface mine power output (kW), see Electrical System (section 2.2.4.2.). For underground mine and mineral processing plant power demand (kV·A), see Electrical System [sections 4.2.5.3. and 6.1.8.4. (IC 9143)].

ADJUSTMENT FACTORS

Power Rate If power is to be supplied by more than one unit, the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curve. After the unit-cost has been calculated, the cost must be multiplied by the total number of units used.

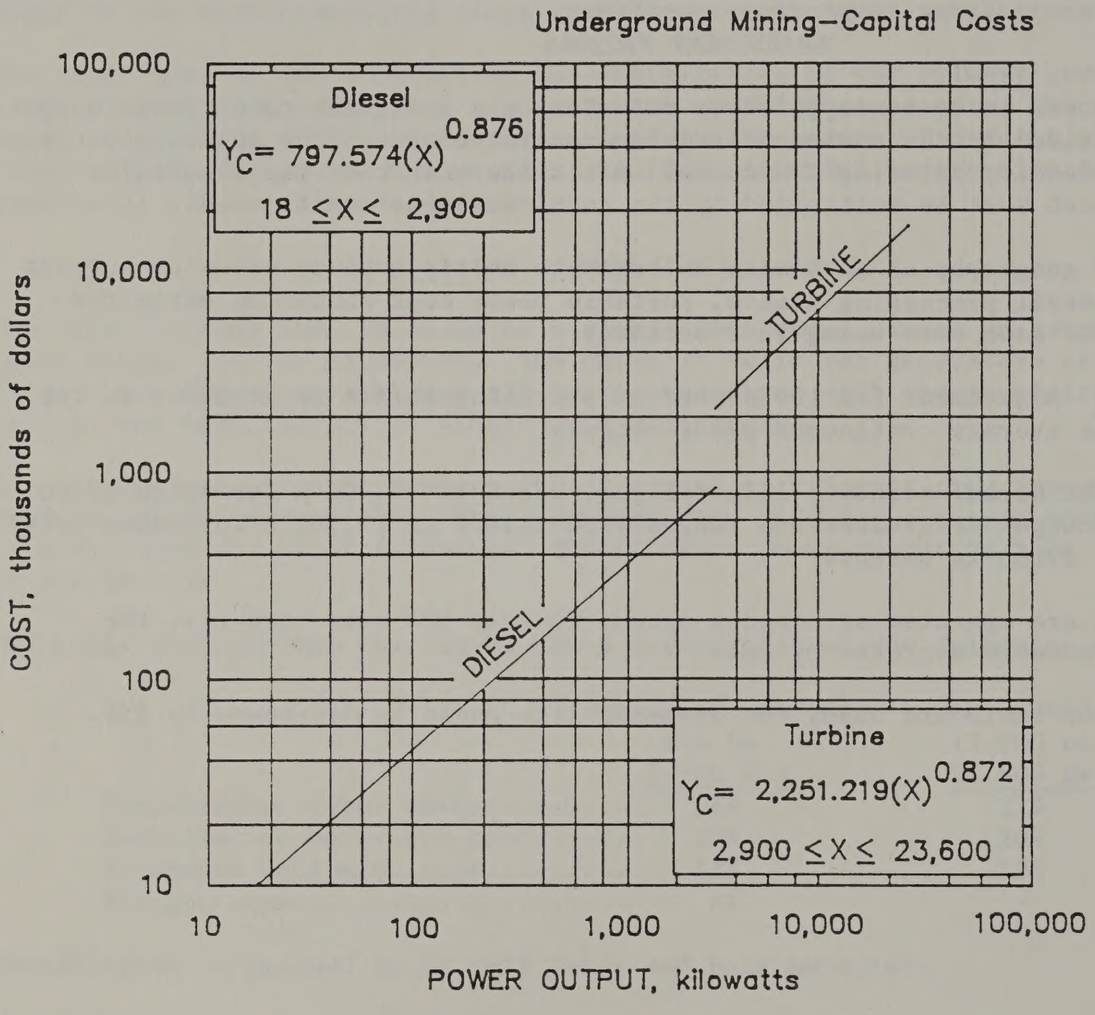
Power Source If geography or economics necessitate multiple power sites to support mines and mineral processing plants, portable power cost should be estimated separately for each site using this section.

Shift Adjustment Adjustment for the number of operating shifts is implicit in the choice of the average continuous power output.

Economic Life The normal economic life for generators is 25,000 h for units rated at 1,100-kW output or greater and ranges from 11,000 to 17,500 h for units rated at less than 1,100-kW output.

If the units are operated at standby rates, roughly 10% over capacity, the economic life would decrease by 50%.

If high-sulfur fuels are used, the economic life would be decreased by 25%.



4.2.5.7. Portable power generation

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.8. REPAIR SHOPS AND WAREHOUSES

In this section underground and surface facilities for repairing and ware- housing mine equipment and supplies are presented separately. Total capital cost is the summation of the two categories. If a mine's primary haulage system utilizes trackless equipment with an adit entry and/or has all repair shops and warehouses located on the surface and underground, the estimator should refer to section 2.2.4.7. (Surface Mine Repair Shops and Warehouses).

BASE CURVES

Repair shop and warehouse capital cost curves include all costs associated with acquisition, installation, and equipping of repair shops and warehouses for an underground mining operation. Repair shops are adequately equipped to maintain and repair virtually all mine equipment.

The total capital cost is based on a single cost curve having an area (X), in square meters of floor space or on a single cost curve having a production rate (T), in metric tons ore and waste mined per day (a typical waste tonnage of 10% is assumed; if this percentage is substantially exceeded, the total tonnage should be used for T). The curve is valid for areas between 40 and 17,000 m^2 (300 to 3,400 m^2 for underground facilities and 40 to 17,000 m^2 for surface facilities), or 300 to 63,000 mtpd, operating two mining shifts per day.

SURFACE REPAIR SHOP AND WAREHOUSE FACILITIES

The surface facilities capital costs are based on single-story steel building construction for Denver, CO, area weather requirements. If surface repair shop and warehouse space requirements are known the capital cost estimate may be made directly by consulting the curve (the curve is valid for areas between 40 and 17,000 m^2). If surface repair shop and warehouse space requirements are not known, they can be estimated from the following equation:

Square meters = $0.500(T)^{0.952}$
where: T = ore and waste mined, in metric tons per day.

The final surface repair shop and warehouse cost derived from the curve is a combination of the following costs:

	Small (40 to 9,000 m^2)	Large (9,000 to 17,000 m^2)
Construction labor cost.....	34%	42%
Construction supply cost....	42%	51%
Purchased equipment cost....	24%	7%

The total surface repair shop and warehouse capital cost is ($Y_{C\ \text{SURFACE-SQUARE METERS}}$) = $1,089.174(X)^{0.856}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-SM-SQ\ M}}) = 272.294(X)^{0.856}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-SM-SQ\ M}}) = 337.644(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-SM-SQ\ M}}) = 479.237(X)^{0.856}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-LG-SQ\ M}}) = 457.453(X)^{0.856}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-LG-SQ\ M}}) = 555.479(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-LG-SQ\ M}}) = 76.242(X)^{0.856}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-AVG-SQ\ M}}) = 370.319(X)^{0.856}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-AVG-SQ\ M}}) = 446.561(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-AVG-SQ\ M}}) = 272.294(X)^{0.856}$

The total surface repair shop and warehouse capital cost is $(Y_{C\ \mathrm{SURFACE-MTPD}}) = 862.559(T)^{0.792}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-SM-MTPD}}) = 362.275(T)^{0.792}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-SM-MTPD}}) = 267.393(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-SM-MTPD}}) = 379.526(T)^{0.792}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-LG-MTPD}}) = 521.676(T)^{0.792}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-LG-MTPD}}) = 439.905(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-LG-MTPD}}) = 60.379(T)^{0.792}$

(L) Construction Labor Cost $(Y_{L\ \mathrm{SURF-AVG-MTPD}}) = 293.270(T)^{0.792}$
(S) Construction Supply Cost $(Y_{S\ \mathrm{SURF-AVG-MTPD}}) = 353.649(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SURF-AVG-MTPD}}) = 215.640(T)^{0.792}$

UNDERGROUND REPAIR SHOP AND WAREHOUSE FACILITIES

Underground facility costs are based on excavating and equipping well-illuminated, painted, and concrete-floored repair shops and warehouses. If underground repair shop and warehouse space requirements are known the capital cost estimate may be made directly by consulting the curve (the curve is valid for areas between 300 to 3,400 m^2). If space requirements are not known they can be estimated from the following equation:

Square meters = $53.646(T)^{0.376}$
where: T = ore and waste mined, in metric tons per day.

The final underground repair shop and warehouse cost derived from the curve is a combination of the following costs:

	Small (300 to 2,300 m^2)	Large (2,300 to 3,400 m^2)
Construction labor cost.....	23%	21%
Construction supply cost....	30%	29%
Purchased equipment cost....	47%	50%

The total underground repair shop and warehouse capital cost is $(Y_{C\ \mathrm{UNDERGROUND-SQUARE\ METER}}) = 79.664(X)^{1.189}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ UG\text{-}SM\text{-}SQ\ M}) = 20.713(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}SM\text{-}SQ\ M}) = 31.866(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}SM\text{-}SQ\ M}) = 27.086(X)^{1.189}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}LG\text{-}SQ\ M}) = 16.729(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}LG\text{-}SQ\ M}) = 23.103(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}LG\text{-}SQ\ M}) = 39.832(X)^{1.189}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}AVG\text{-}SQ\ M}) = 18.323(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}AVG\text{-}SQ\ M}) = 25.492(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}AVG\text{-}SQ\ M}) = 35.849(X)^{1.189}$

The total underground repair shop and warehouse capital cost is $(Y_{C\ UNDERGROUND\text{-}MTPD}) = 8{,}425.625(T)^{0.457}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ UG\text{-}SM\text{-}MTPD}) = 2{,}190.663(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}SM\text{-}MTPD}) = 3{,}370.250(T)^{0.457}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}SM\text{-}MTPD}) = 2{,}864.712(T)^{0.457}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}LG\text{-}MTPD}) = 1{,}769.381(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}LG\text{-}MTPD}) = 2{,}443.431(T)^{0.457}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}LG\text{-}MTPD}) = 4{,}212.813(T)^{0.457}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}AVG\text{-}MTPD}) = 1{,}937.894(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}AVG\text{-}MTPD}) = 2{,}696.200(T)0.457$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}AVG\text{-}MTPD}) = 3{,}791.531(T)^{0.457}$

ADJUSTMENT FACTORS

Weather Factor For underground mines with surface facilities located in climates that vary from the Denver, CO, area, multiply labor and supplies portions of the costs obtained from the surface facilities curve by the following factors:

Mild areas:
Labor factor $(F_{L\ SURFACE\text{-}MILD}) = 0.94$

Supplies factor $(F_{S\ SURFACE\text{-}MILD}) = 0.94$

Severe areas:
Labor factor $(F_{L\ SURFACE\text{-}SEVERE}) = 1.08$

Supplies factor $(F_{S\ SURFACE\text{-}SEVERE}) = 1.08$

Room-and-Pillar Mine Factor For room and pillar mines with underground facilities emplaced in mined out areas, multiply the costs obtained from the curves by the following factors:

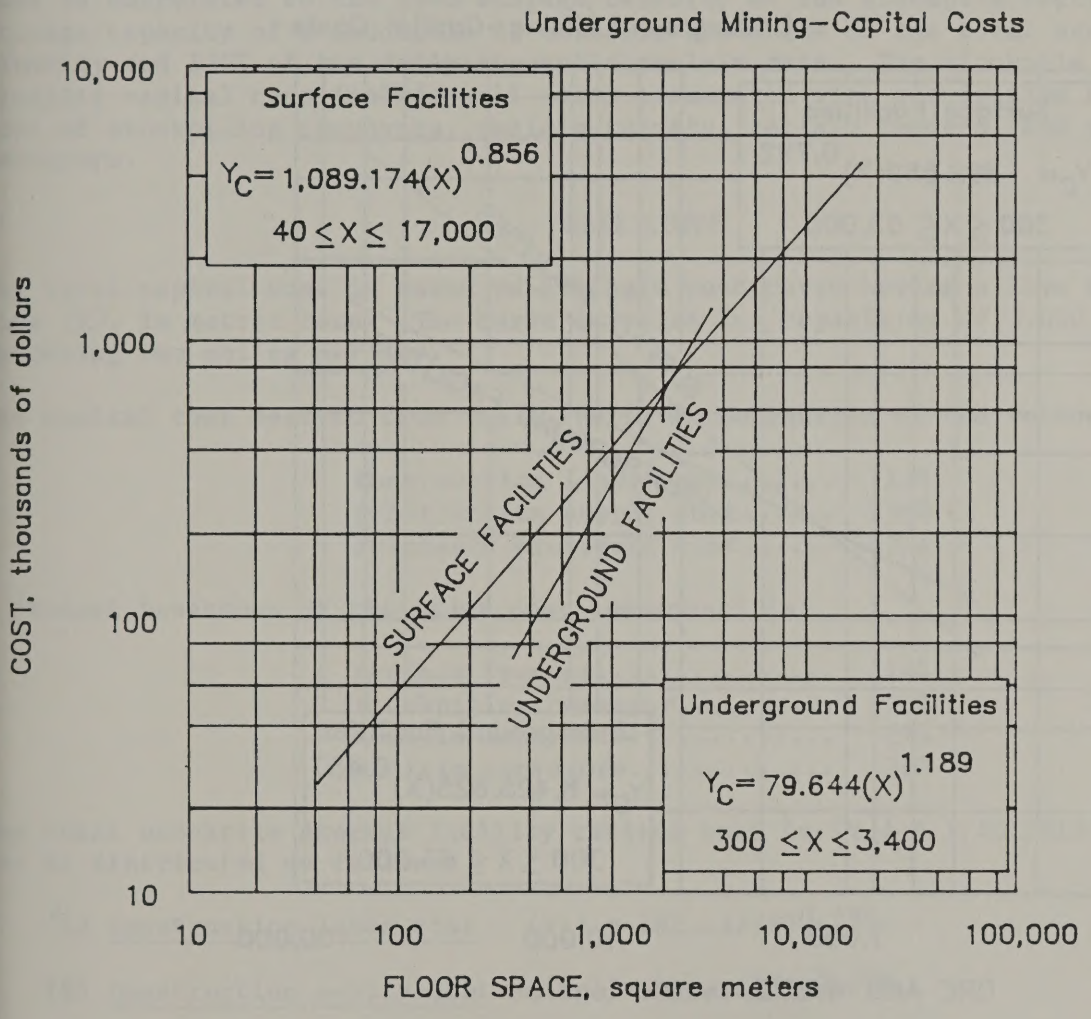
Labor factor $(F_{L\ R\&P\ MINED\ OUT\ AREAS}) = 0.48$

Supplies factor $(F_{S\ R\&P\ MINED\ OUT\ AREAS}) = 0.41$

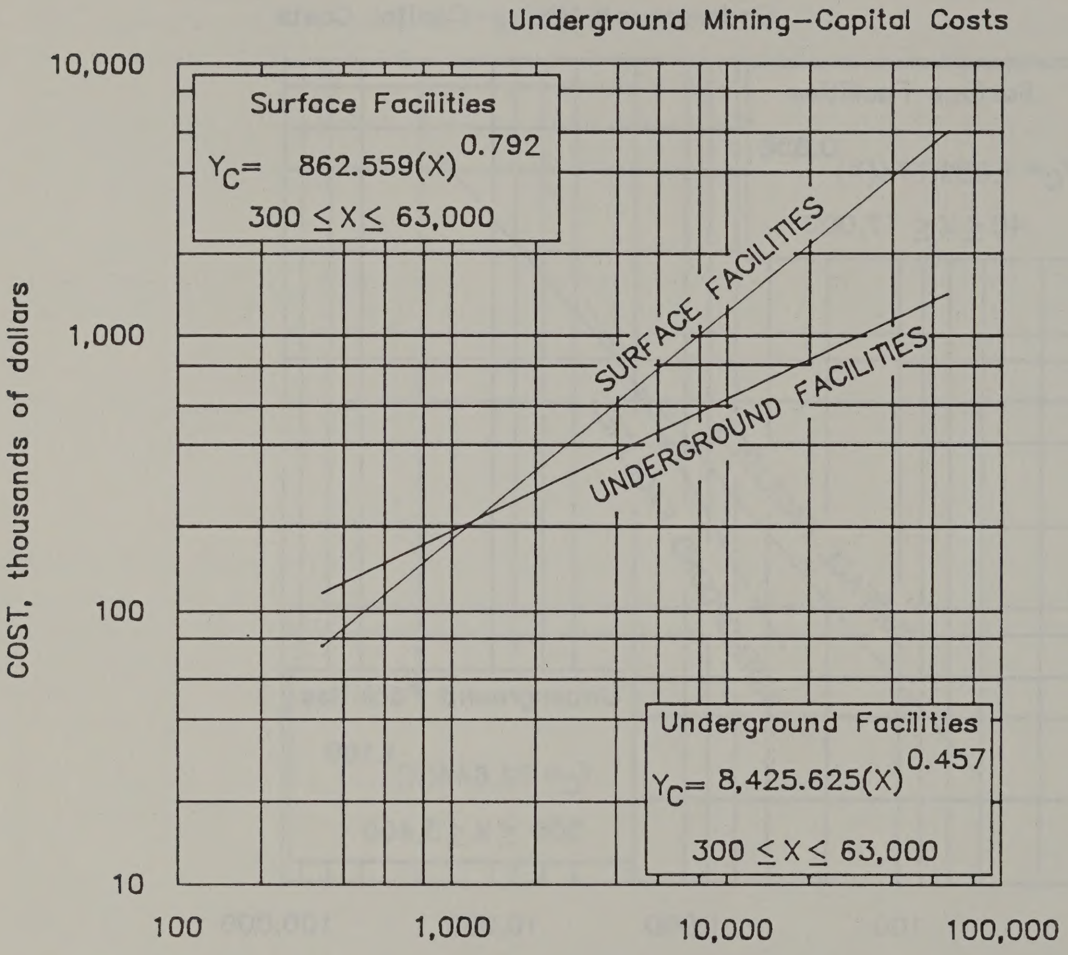
Multilevel Mine Factor Multilevel mines commonly have satellite shops on each active producing level for equipment maintenance and minor repairs. The cost for satellite repair shops is

Satellite repair shops cost $(Y_S) = (N)9.710(T)^{0.914}$
where N = number of active producing levels,
and T = ore mined, in metric tons per day.

Add the cost for satellite repair shops to the costs obtained from the curves to obtain a total cost.



4.2.5.8.a Repair shops and warehouses



4.2.5.8.b Repair shops and warehouses

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.9. STOCKPILE STORAGE FACILITIES

A stockpile storage facility provides sufficient storage capacity for a material until it can be further processed. A storage facility may also provide adequate reserve material to dampen surges in the material supply. Examples of materials stockpiled are smelter flux, coal, and coarse ore. For this base curve, capital cost is correlated to the live storage capacity of the stockpile facility. Live storage capacity of a stockpile is normally about 25% of the total stockpile capacity and 150% of the daily stockpile reclaim rate. The stockpile storage facility capital cost includes all costs associated with acquisition and installation of stockpiling conveyors, reclaim tunnels, reclaim feeders, and reclaim conveyors.

BASE CURVE

The total capital cost is based on a single cost curve having a live storage capacity (X), in metric tons. The curve is valid for capacities of 3,000 to 300,000 mt, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	13%
Construction supply cost......	36%
Purchased equipment cost......	51%

A typical breakdown of the major cost components is:

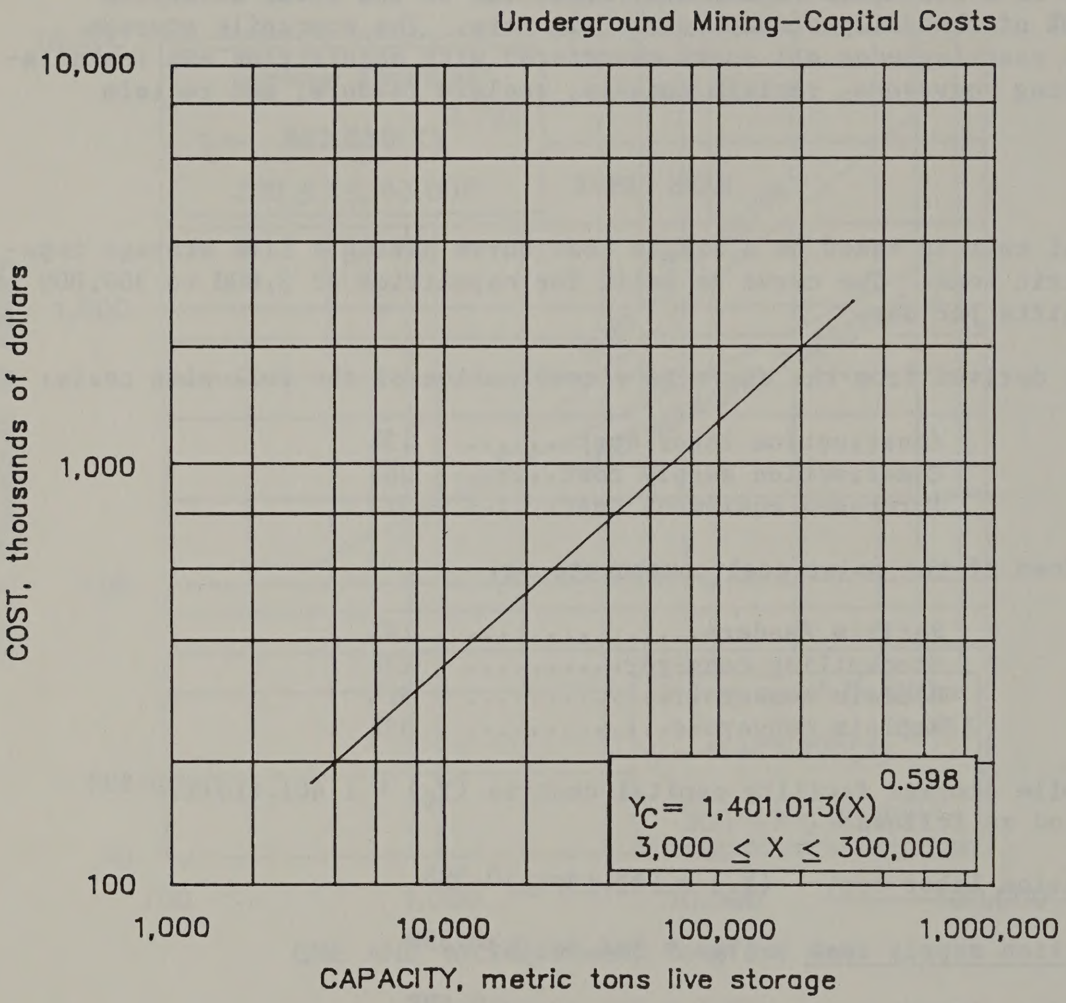
Reclaim feeders...............	14%
Stockpiling conveyor..........	23%
Reclaim tunnels...............	31%
Reclaim conveyors.............	32%

The total stockpile storage facility capital cost is $(Y_C) = 1{,}401.013(X)^{0.598}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 182.132(X)^{0.598}$

(S) Construction supply cost $(Y_S) = 504.365(X)^{0.598}$

(E) Purchased equipment cost $(Y_E) = 714.516(X)^{0.598}$



4.2.5.9. Stockpile storage facilities

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.10. SURFACE BUILDINGS

Surface building capital costs cover the general support facilities required for the mining operation. The buildings are single-story construction. The total capital cost is based on a single cost curve having a combined floor space (X), in square meters or having a production rate (T), in total metric tons of ore and waste per day. The curve is valid for areas of 20 to 20,000 m^2, or production rates of 290 to 12,000 mtpd, operating three shifts per day.

BASE CURVE

Through use of the base curve, the evaluator may determine the total cost of all buildings covered in this category. These buildings include the change house, powder magazines, lamproom, first aid room, guard house, and security fences. The determined cost encompasses construction material, construction labor, as well as purchase and installation of the building fixtures.

If the total required floor space is not known, the final cost may be estimated by first determining the staffing or labor requirements needed based on the number of metric tons to be mined each day. In a three-shift-per-day operation, the surface building area needed equals approximately 2.23 m^2 for each individual employed in the mining operation. By taking the daily tonnage mined and dividing that number by the appropriate tonnage per worker ratio found in the tabluation on the following page, one derives an estimate of the daily labor requirements. If this value is further divided by three shifts per day and the resultant answer multiplied by 2.23, an estimate of the square meter requirements for surface buildings can be achieved.

Square meters requirement $(X_S) = 0.743(T/R)$
where T = ore and waste mined, in metric tons per day,
and R = metric tons per worker-shift ratio (see tabluation on following page).

The final answer is then entered into the square meters base curve equation.

The surface buildings capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	32%
Construction supply cost......	51%
Purchased equipment cost......	17%

The total surface buildings capital cost is $(Y_C \text{ SQUARE METERS}) = 8,987.000(X)^{0.684}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \text{SQUARE METERS}}) = 2{,}875.840(X)^{0.684}$

(S) Construction Supply Cost $(Y_{S\ \text{SQUARE METERS}}) = 4{,}583.370(X)^{0.684}$

(E) Purchased Equipment Cost $(Y_{E\ \text{SQUARE METERS}}) = 1{,}527.790(X)^{0.684}$

The total surface buildings capital cost is $(Y_{C\ \text{MTPD}}) = 13{,}552.211(T)^{0.436}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \text{MTPD}}) = 4{,}336.708(T)^{0.436}$

(S) Construction Supply Cost $(Y_{S\ \text{MTPD}}) = 6{,}911.628(T)^{0.436}$

(E) Purchased Equipment Cost $(Y_{E\ \text{MTPD}}) = 2{,}303.876(T)^{0.436}$

Productivity of mining methods

	Metric tons/worker-shift ratio	
Method	Normal	High
Room and pillar........	27-45	45-64
Sublevel caving........	18-36	36-45
Block caving...........	14-36	36-45
Sublevel stoping.......	14-27	27-36
Cut and fill mining....	9-18	18-25
Shrinkage stoping......	4.5- 9	9-14
Square set mining......	1- 3	NAp

NAp Not applicable.

Source: Modified from Society of Mining Engineers AIME Underground Mining Methods Handbook, ed. by W.A. Hustrulid, 1982, p. 109.

ADJUSTMENT FACTORS

Joint Facility Factor If mine and mill share these facilities it is important to reduce the capital cost of the mine section appropriately. To determine the capital cost in this instance, calculate the total space requirements for both mine and mill and the percentage each facility requires. The amount to be accounted to mine capital cost can be then calculated, using the base curve, from the mine's percentage of the total space requirements.

Weather Factor For surface buildings located in climates that vary from the Denver, CO, area, multiply the labor and supplies costs obtained from the curves by the following factors:

Mild areas:

Labor factor $(F_{L\ \text{MILD}}) = 0.960$

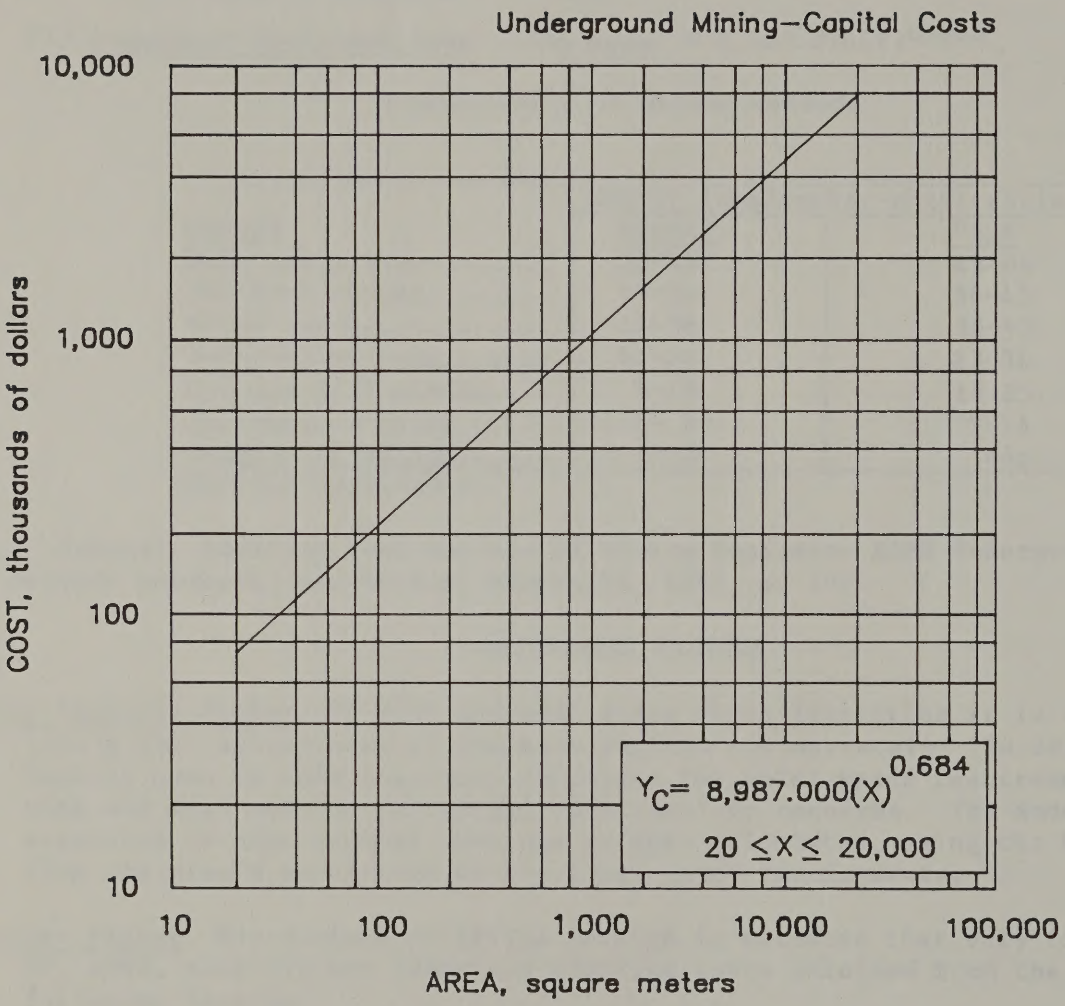
Supply factor $(F_{S\ \text{MILD}}) = 0.940$

Severe areas:

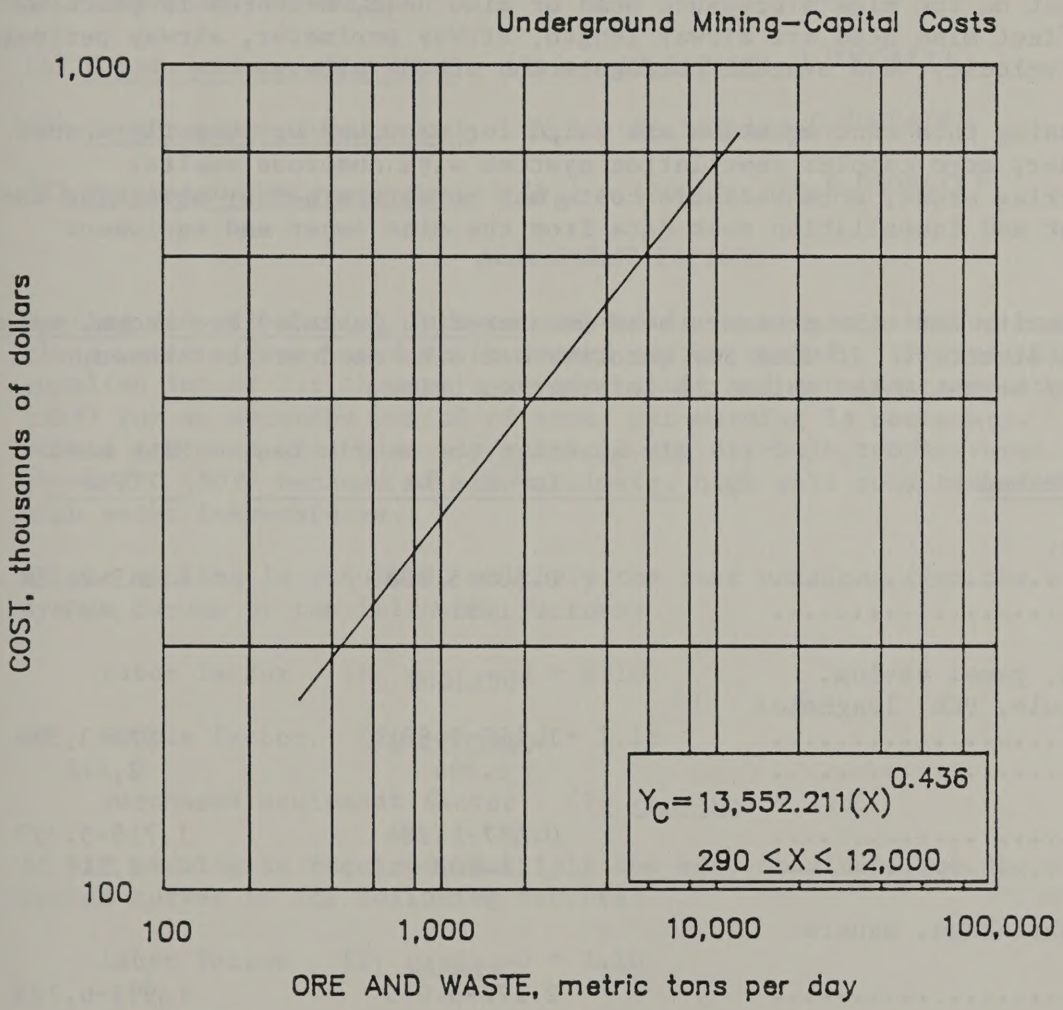
Labor factor $(F_{L\ \text{SEVERE}}) = 1.080$

Supply factor $(F_{S\ \text{SEVERE}}) = 1.080$

Shift Factor Where a proposed mine will be operating less than three shifts per day, the surface building requirements will rise a fractional amount. The additional floor space for the change house should be determined and included with the value used in the base curve equation.



4.2.5.10.a Surface buildings



4.2.5.10.b Surface buildings

4.2.5.11. VENTILATION SYSTEM

Mine ventilation system capital and operating costs are dependent on the energy to move a quantity of air through a mine. Some factors that determine mine air quantity, measured in cubic meters per minute, are the number of personnel underground, diesel equipment operation, presence or absence of methane, and air temperature and humidity. Energy, measured in kilowatts, required to move an air quantity through a mine is dependent on the mine's pressure head or mine head, measured in pascals. Factors that affect mine head are airway length, airway perimeter, airway perimeter roughness, air velocity, and overall configuration of the airways.

Costs derived using this cost-equation are valid for proposed or recently opened mines. For older, more complex ventilation systems with numerous shafts, levels, and working areas, more reliable costs may be determined by obtaining the actual equipment and installation cost data from the mine owner and equipment manufacturers.

If mine air quantity and mine pressure head (measured in pascals) are known, consult the base curves directly. If mine air quantity and mine head are not known, requirements may be estimated using the information below.

Mining Method	Air quantity per metric ton (m^3/min/mt)	Mine head (Pa)
Room and pillar:		
Range..........................	0.539-5.208	1,245-2,191
Average........................	1.917	1,609
Sublevel caving, panel caving, sublevel blasthole, VCR, longhole:		
Range..........................	1.158-7.881	872-3,586
Average........................	3.394	2,111
Block caving:		
Range..........................	0.607-1.784	1,718-5,727
Average........................	1.163	2,117
Cut and fill, shrinkage, square set:		
Range..........................	2.172-5.073	1,992-6,723
Average........................	3.789	4,171

(Pressure head conversions 1 psi = 27.7 in H_2O = 6.8948 kPa)

BASE CURVE

Total cost is based on a single cost curve having a mine air quantity demand (X), in cubic meters per minute. The curve is valid between 1,000 and 60,000 m^3/min, operating three shifts per day. The excavation cost for airways (i.e. drifts, crosscuts, shafts, and/or raises) are not included in this curve and should be derived in section 4.2.1., Preproduction Development.

The ventilation curve cost includes the installed cost of the main ventilation system and acquisition cost of auxiliary ventilation equipment. Main system installation includes the cost of labor, fans, foundations, motors, ductwork, bulkheads, and air doors.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	19%
Construction supply cost.......	13%
Purchased equipment cost.......	68%

The total ventilation system capital cost is $(Y_C) = 278{,}119.058e^{0.00004(X)}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 52{,}842.621e^{0.00004(X)}$

(S) Construction Supply Cost $(Y_S) = 36{,}155.478e^{0.00004(X)}$

(E) Purchased Equipment Cost $(Y_E) = 189{,}120.959e^{0.00004(X)}$

ADJUSTMENT FACTORS

Air-Cooling and Air-Warming Factors Depending on climatic and/or underground conditions, mine air may need to be warmed and/or cooled. If a ventilation system supplies intake air through a service shaft and outside temperatures go below 0C (32F) for an extended period of time, air-warming is necessary. Air-cooling plants are used when mine air wet-bulb and dry-bulb temperatures are near or above 27C (80F) because of a hot climate, high wall rock temperatures, and/or high water temperatures.

If air cooling is required, multiply the cost obtained from the ventilation system curves by the following factors:

Labor factor $(F_{L\ COOLING}) = 1.10$

Supply factor $(F_{S\ COOLING}) = 1.15$

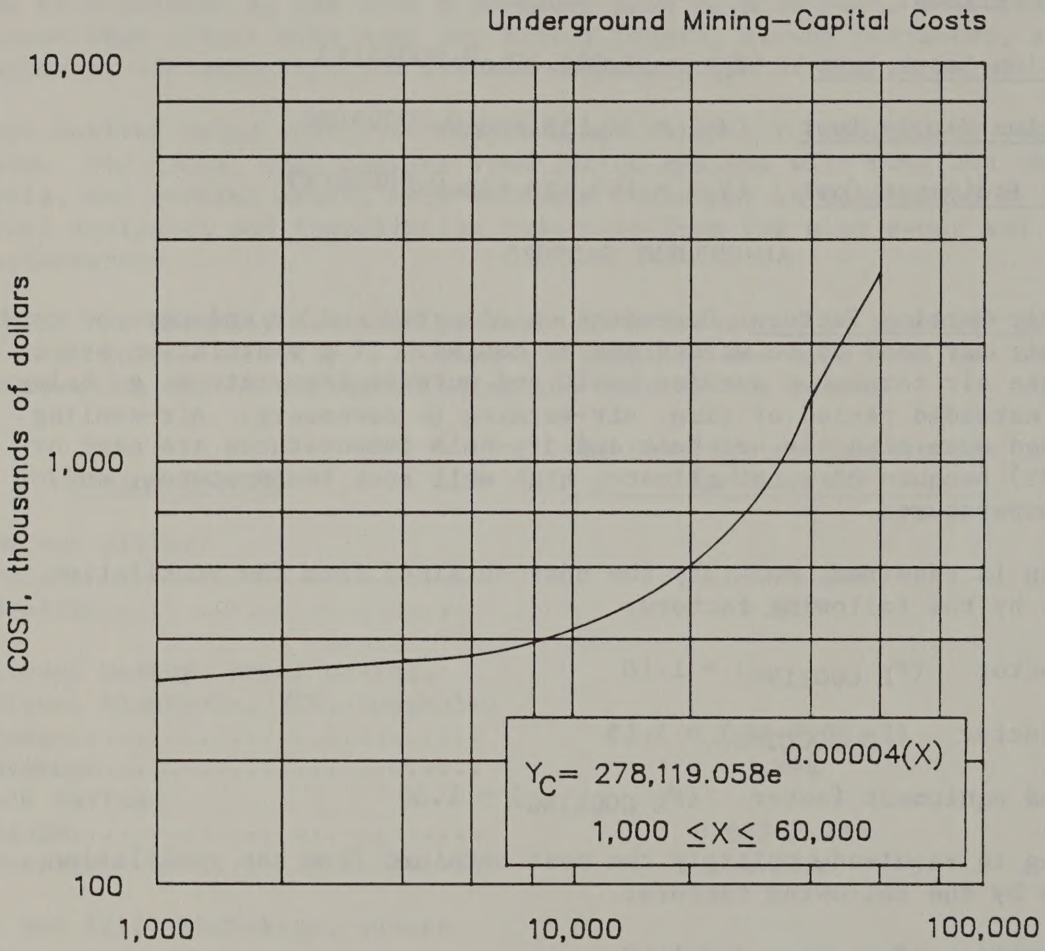
Purchased equipment factor $(F_{E\ COOLING}) = 1.30$

If air warming is required, multiply the cost obtained from the ventilation system curves by the following factors:

Labor factor $(F_{L\ WARMING}) = 1.10$

Supply factor $(F_{S\ WARMING}) = 1.11$

Purchased equipment factor $(F_{E\ WARMING}) = 1.10$



4.2.5.11. Ventilation system

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.12.1. WATER AND DRAINAGE SYSTEM
DRAINAGE AND DISPOSAL SYSTEM

The capital cost of a drainage system is based upon the volume of water pumped daily from the underground workings. The system is composed of pumping equipment, pipes, connectors, valves, sumps, service adits and pumping stations, formwork, concrete flooring, miscellaneous wiring, and maintenance equipment. Discharged water is pumped through piping to a surface mill or tailings pond.

BASE CURVE

The total capital cost is based on a single curve having a water discharge rate (X), in cubic meters per day. The curve is valid for pumping operations between 600 and 20,000 m^3/d, operating 24 h/d. A standard pumping height of 610 m (2,000 ft) is used. Allowances have been made for pumping head versus pumping height. As individual cases will invariably require adjustment for depth, an appropriate factor is given in the adjustments section below.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	15%
Construction supply cost......	19%
Purchased equipment cost......	66%

The total drainage supply system capital cost is $(Y_C) = 1{,}093.057(X)^{0.690}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 163.959(X)^{0.690}$

(S) Construction Supply Cost $(Y_S) = 207.681(X)^{0.690}$

(E) Purchased Equipment Cost $(Y_E) = 721.418(X)^{0.690}$

ADJUSTMENT FACTORS

Total Pumping Height When pumping heights differ from the 610 m (2,000 ft) standard used here, multiply the costs obtained from the drainage and disposal curves by the following factor:

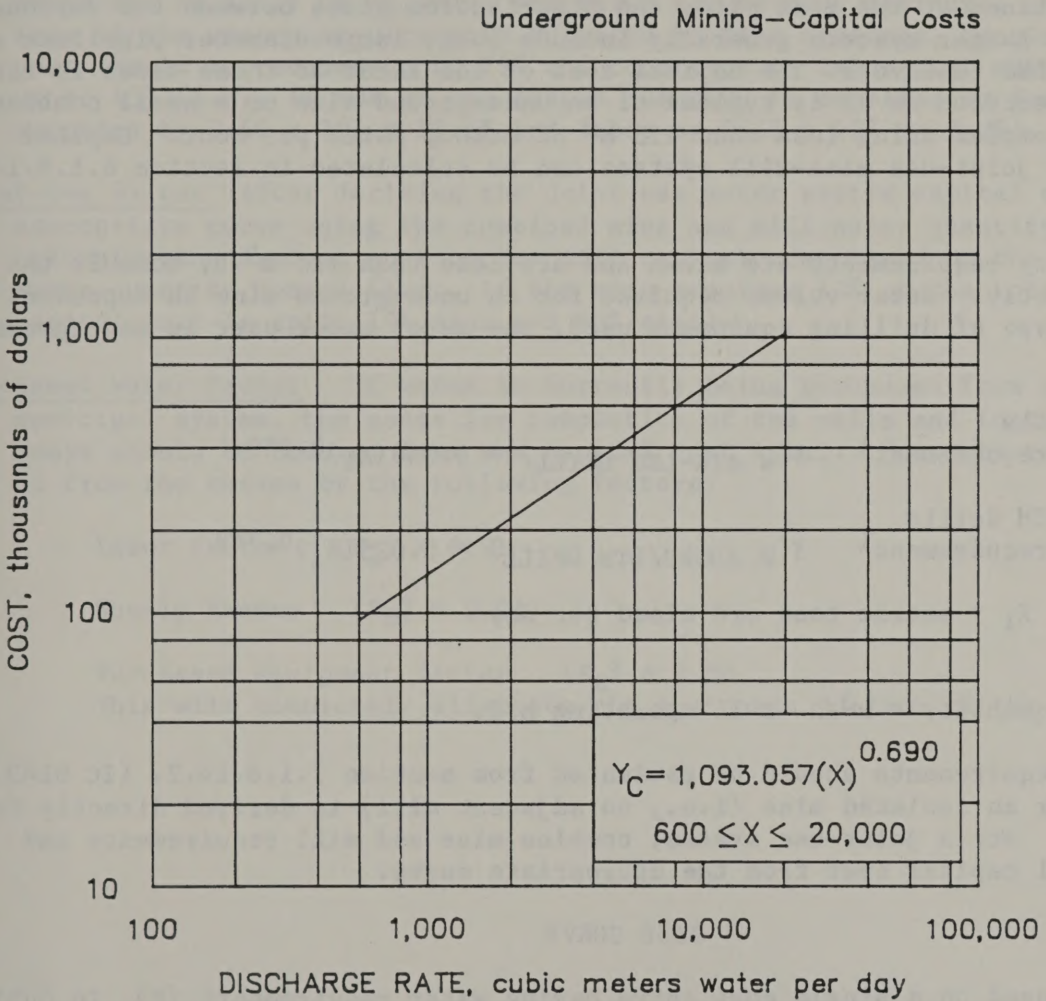
Height factor $(F_H) = 0.642e^{0.0008(H)}$
where: H = actual pumping head, in meters.

Horizontal Drainage Factor If drainage water is collected, and initial settling occurs in sumps located in the mine prior to pumping the water out through the portal of an adit (rather than up a shaft), multiply the costs obtained from the drainage and disposal curves by the following factor:

Horizontal drainage factor $(F_{D\ \mathrm{SETTLING}}) = 0.37$
This cost is distributed 36% for labor, 44% for supplies, and 20% for equipment.

If drainage water is pumped directly out of an adit portal without initial settling, multiply the costs obtained from the drainage and disposal curves by the following factor:

Horizontal drainage factor $(F_{D\ \mathrm{NO\ SETTLING}}) = 0.22$
This cost is distributed 32% for labor, 39% for supplies, and 29% for equipment.



4.2.5.12.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

4.2.5.12.2. WATER AND DRAINAGE SYSTEM
WATER SUPPLY SYSTEM (MAKEUP WATER)

The capital cost of a water supply system is based on volume demand and includes a method for collection, storage, and distribution of water. A mine and mill near to each other typically use the same water system. Water systems capable of supplying up to 125 m^3/h (550 gal/min) of makeup water usually comprise a system of wells, storage tanks at the mine site, and distribution lines between the various use locations. Larger systems generally include long, large-diameter pipelines and/or an earthen dike reservoir. The capital cost of the first of these cases is discussed in this section as it is typical of an underground mine or a small combined mine and mill complex using less than 125 m^3 of makeup water per hour. Capital cost for larger joint-use mine-mill systems can be calculated in section 6.1.8.14 (IC 9143).

If water quantity requirements are known and are less than 125 m^3/h, consult the base curve directly. Water volume required for an underground mine is dependent on the principle type of drilling equipment used, the major water user in underground mines.

Air-leg drills

Water requirement[1] $Y(_{W\ AIR\text{-}LEG\ DRILL}) = 0.049(X_1)^{0.889}$

Jumbo and DTH drills

Water requirement[1] $Y(_{W\ JUMBO/DTH\ DRILL}) = 0.025(X_1)^{0.749}$

where: X_1 = metric tons ore mined per day

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[1] Daily water quantity = m^3/h x 16 operating h/d.

Mill quantity requirements should be estimated from section 7.1.8.14.2. (IC 9143). Capital cost for an isolated mine (i.e., no adjacent mill) is derived directly from the base curve. For a joint-use system, combine mine and mill requirements and derive the total capital cost from the appropriate curve.

BASE CURVE

Total cost is based on a single cost curve having water requirements (X), in cubic meters per day. The curve is valid for water volumes between 40 and 2,000 m^3/d, operating two shifts per day. The curve includes all costs associated with completion of wells, purchase and installation of pumps, storage tanks, and surface distribution lines.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	37%
Construction supply cost......	55%
Purchased equipment cost......	8%

The total water supply system capital cost is $(Y_C) = 1{,}477.799(X)^{0.693}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 546.786(X)^{0.693}$

(S) Construction Supply Cost $(Y_S) = 812.789(X)^{0.693}$

(E) Purchased Equipment Cost $(Y_E) = 118.224(X)^{0.693}$

ADJUSTMENT FACTORS

Mine Drainage Factor The user should be aware that mine and/or mill water requirements can be fully or at least partially met by mine drainage. Based on percentage of the system requirements supplied by mine drainage, construction supply cost should be reduced up to 29% and construction labor cost should be reduced up to 43% (i.e., if 40% of the system quantity is supplied by drainage, reduce supplies by 0.40 x 29% = 11.6% and labor by 0.40 x 43% = 17.2%).

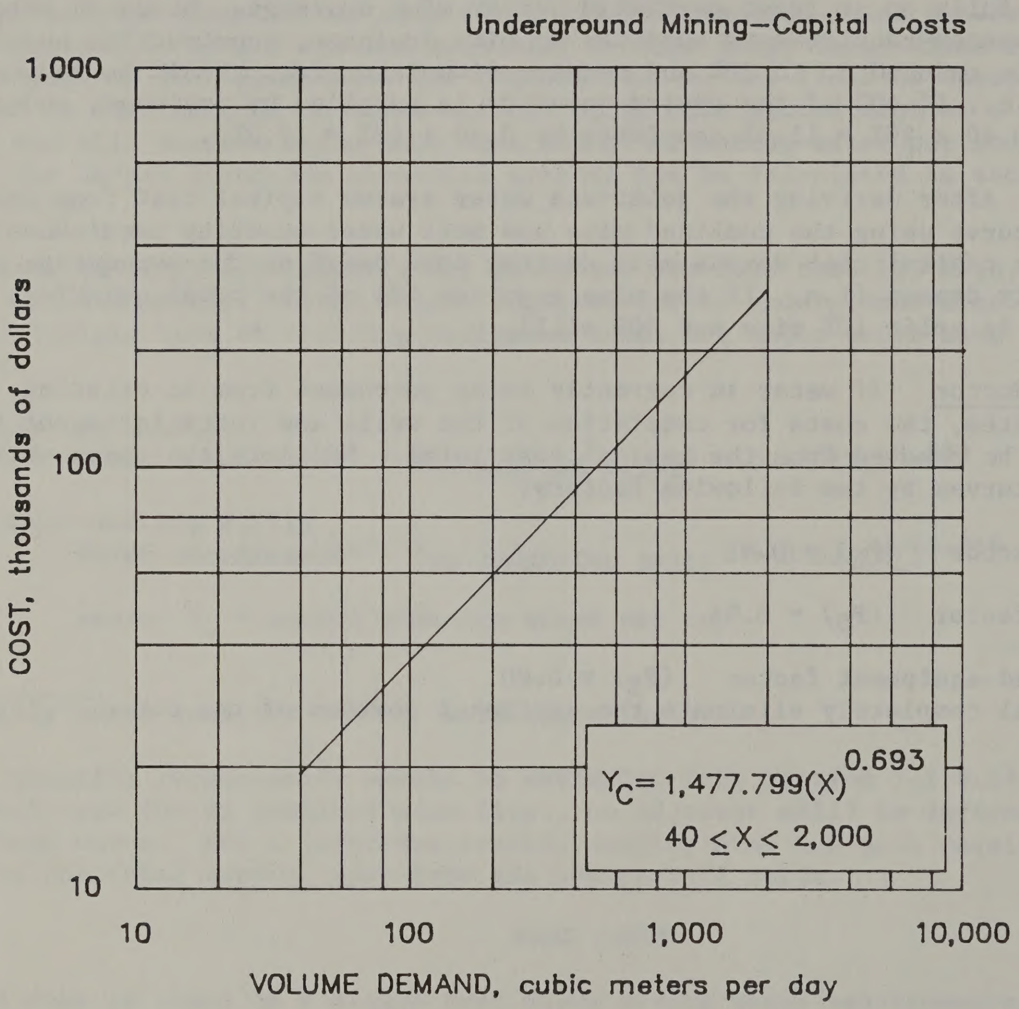
Joint-Use Factor After deriving the joint-use water system capital cost from the appropriate curve using the combined mine and mill water quantity requirements, allocate mine capital cost versus mill capital cost based on the percentage of water quantity demand (i.e., if the mine requires 10% of the total quantity, capital cost is split 10% mine and 90% mill).

Purchased Water Factor If water is currently being purchased from an existing municipal system, the costs for completion of the wells and installation of the pumps should be removed from the capital cost total. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.91$

Supply factor $(F_S) = 0.94$

Purchased equipment factor $(F_E) = 0.00$
This will completely eliminate the equipment portion of the curve.



4.2.5.12.2. Water and disposal system
WATER SUPPLY SYSTEM (MAKEUP WATER)

4.2.7. INFRASTRUCTURE

4.2.7.1.1. ACCESS ROADS CLEARING

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with clearing for access roads. Supplies have not been considered in the clearing costs because it is assumed that cleared brush or timber would be buried under the excavation waste; thus, supplies of fuel oil for burning the clearing slash are not required.

BASE CURVE

The curves are based on estimated costs for clearing medium growth on terrain with a side slope of 25%. Medium growth varies from heavy brush to one tree, 0.33 m in diameter, per 40 m^2.

(L) Labor Operating Cost $(Y_L) = 1135.467(X)^{0.711}$
The operating labor costs are distributed as follows:

Direct labor................	86%
Maintenance labor...........	14%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator............	12%	$16.33
Wheel-loader operator......	12%	16.33
Flatbed-truck driver.......	12%	15.89
General laborer............	64%	13.86

The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 467.945(X)^{0.711}$
The equipment operating cost consists of 35% for repair parts, 53% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of:

Dozer crawler..............	31%
Wheel loader...............	47%
Flatbed truck..............	12%
Pickup truck...............	9%
Chainsaws..................	1%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawler..............	52%	48%	-
Wheel loader...............	36%	43%	21%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%
Chainsaws..................	39%	61%	-

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factor:

Brush factor $(F_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(F_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 30% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 30% to 50%,

Side slope factor $(F_{S\ 30\%-50\%}) = 1.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 2.5$

Burning Equation If fuel oil (for burning slash) or other supplies, such as cables and chokers, are used, add the following supply cost equation to the total cost per kilometer. The total cost per kilometer for supplies is for a roadway of width (X), in meters, varying in width from 3 to 30 m.

(S) Supply Operating Cost $(Y_{S\ BURNING}) = 269.796[0.100(X)]^{-0.0303}$

This cost is multiplied by the total kilometers, valid for values between 3.33 to 3,333.33 km, to obtain the capital cost.

For clearing operations from 1 to 500 ha (roadway width in meters multiplied by roadway length in meters multiplied by 0.0001), the supplies consist of 78% for fuel oil and 22% for tools, cables, and chokers. For clearing operations of 500 to 1,000 ha, supplies consist of 83% for fuel oil (for burning wood and scrub) and 17% for tools, cables, and chokers.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

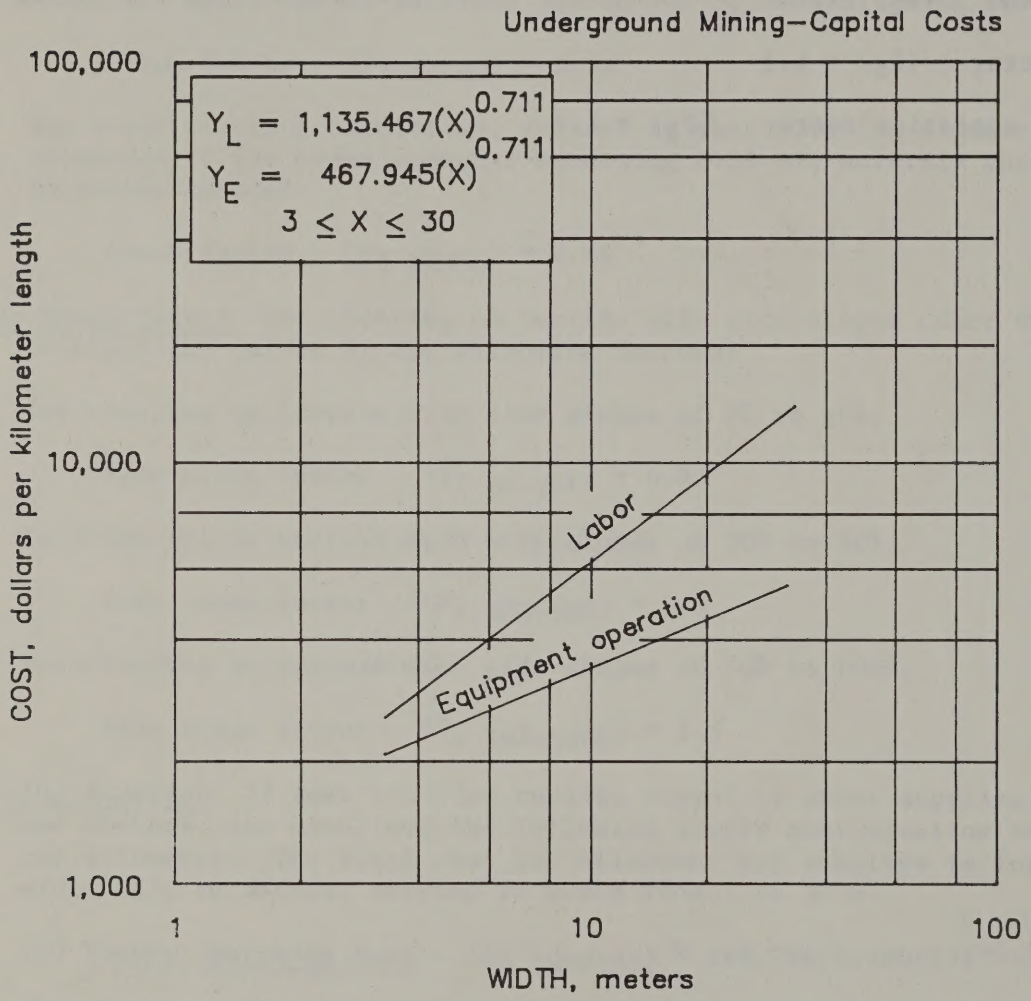
Shifts per day.............	1	2	3
Factor.....................	1.91	1.68	1.61

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curve by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



4.2.7.1.1. Access roads
CLEARING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.1.2. ACCESS ROADS
DRILL AND BLAST

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with drilling and blasting for access roads.

BASE CURVE

The curves are based on estimated costs for drilling and blasting a cut with a single ditch. The terrain has a side slope of 25%, and the cut contains 50% rock.

(L) Labor Operating Cost $(Y_L) = 9,633.822(X)^{0.496}$
The operating labor costs are distributed as follows:

Direct labor...............	79%
Maintenance labor..........	21%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Air-track driller..........	33%	$16.78
Compressor operator........	17%	17.23
Chuck tender...............	27%	13.86
Powderman..................	8%	16.33
Powderman helper...........	7%	14.56
Flatbed-truck driver.......	8%	15.89

The average wage for labor is $15.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7,247.524(X)^{0.644}$
The supply cost consists of 79% blasting supplies and 21% drilling supplies. Drilling supplies consist of percussion drill bits, rods, striking bars, and couplings; blasting supplies consist of dynamite, ANFO, electric blasting caps, and connecting wire.

(E) Equipment Operating Cost $(Y_E) = 4,109.384(X)^{0.496}$
The equipment operation curve consists of 51% for repair parts, 48% for fuel and lubrication, and 1% for tires.

The equipment operation curve consists of:

Air-track drills...........	33%
Portable compressors.......	55%
Flatbed truck..............	7%
Pickup truck...............	5%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Air-track drills...........	93%	7%	-
Portable compressors.......	34%	65%	1%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Rock Factor For drilling and blasting cuts that contain other than 50% rock, multiply the curves by the following factors:

For drilling and blasting cuts containing 25% rock,

Rock factor $(F_{R\ 25\%}) = 0.6$

For drilling and blasting cuts containing 100% rock,

Rock factor $(F_{R\ 100\%}) = 1.4$

Side Slope Factor For terrain with side slopes of 0% to 20% that require drilling and blasting for two ditches and for providing material for a minimum fill, the base curve costs should be used without any adjustments.

For clearing on terrain with side slopes of 20% to 50%, multiply the costs obtained from the curves by the following factors:

Side slope factor $(F_{S\ 20\%-50\%}) = 1.5$

On terrain with side slopes in the range of 50% to 100%, multiply the costs obtained from the curves by the following factors:

Side slope factor $(F_{S\ 50\%-100\%}) = 3.0$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

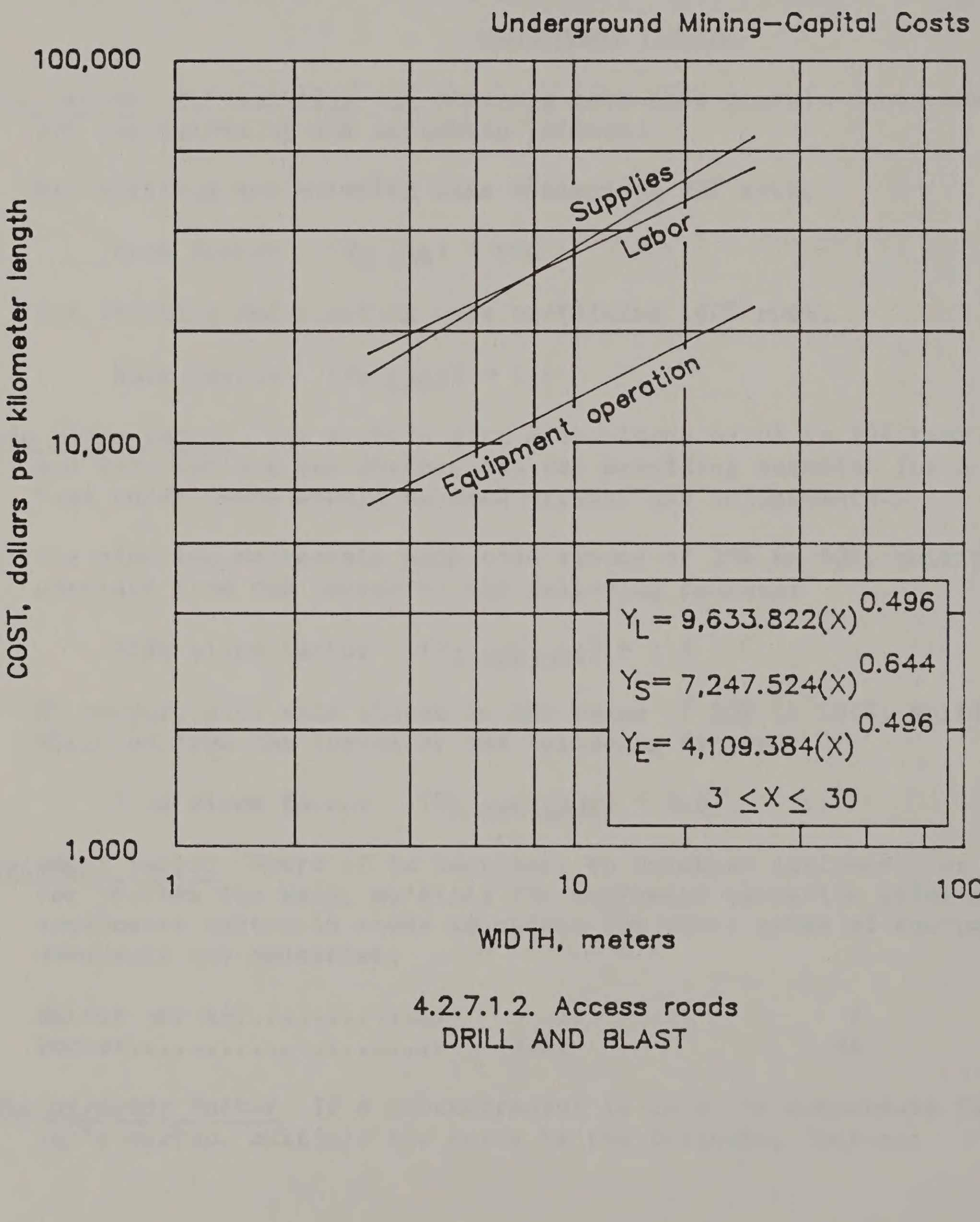
Shifts per day.............	1	2	3
Factor.....................	2.12	1.84	1.75

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



4.2.7.1.2. Access roads
DRILL AND BLAST

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.1.3. ACCESS ROADS
EXCAVATION

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with excavation for access roads.

BASE CURVES

The curves are based on a dozer excavation operation that is working on terrain with a side slope of 25%, side-casting from cuts or ditches to a 30-cm fill or to waste. The material to be excavated is either blasted rock or a common conglomerate that presents some difficulty in cutting and drifting.

(L) Labor Operating Cost $(Y_L) = 29.843(X)^{1.870}$
The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	60%	$16.33
Grader operator............	20%	16.33
Water-truck driver.........	20%	15.89

The average wage for labor is $16.24 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 27.128(X)^{1.870}$
The equipment operation curve consists of 46% for repair parts, 50% for fuel and lubrication, and 4% for tires.

The equipment operation curve consists of

Dozer crawlers.............	47%
Dozer-ripper crawler.......	25%
Motor grader...............	15%
Water truck................	9%
Pickup truck...............	4%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawlers.............	51%	49%	-
Dozer ripper crawler.......	53%	47%	-
Motor grader...............	45%	41%	14%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Side Slope Factor On terrain with a side slope other than 20% to 30%, excavation costs can be determined by multiplying the costs obtained from the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\text{-}20\%}) = [0.8(S)]^{0.600}(W)^{0.756}$
where S = side slope [defined as 1+(percent slope/100)],
and W = roadway width, in meters.

For clearing on terrain with side slopes of 30% to 100%,

Side slope factor $(F_{S\ 30\text{-}100\%}) = [0.8(S)]^{3.958}(W)^{0.087}$
where S = side slope [defined as 1+(% slope/100)],
and W = roadway width, in meters.

Material Factor For excavation of materials that are easy to cut and drift, multiply the costs obtained from the curves by the following factors:

Material factor $(F_{M\ EASY}) = 0.75$

For excavation of extremely wet and sticky material, multiply the curves by the following factors:

Material factor $(F_{M\ DIFFICULT}) = 1.33$

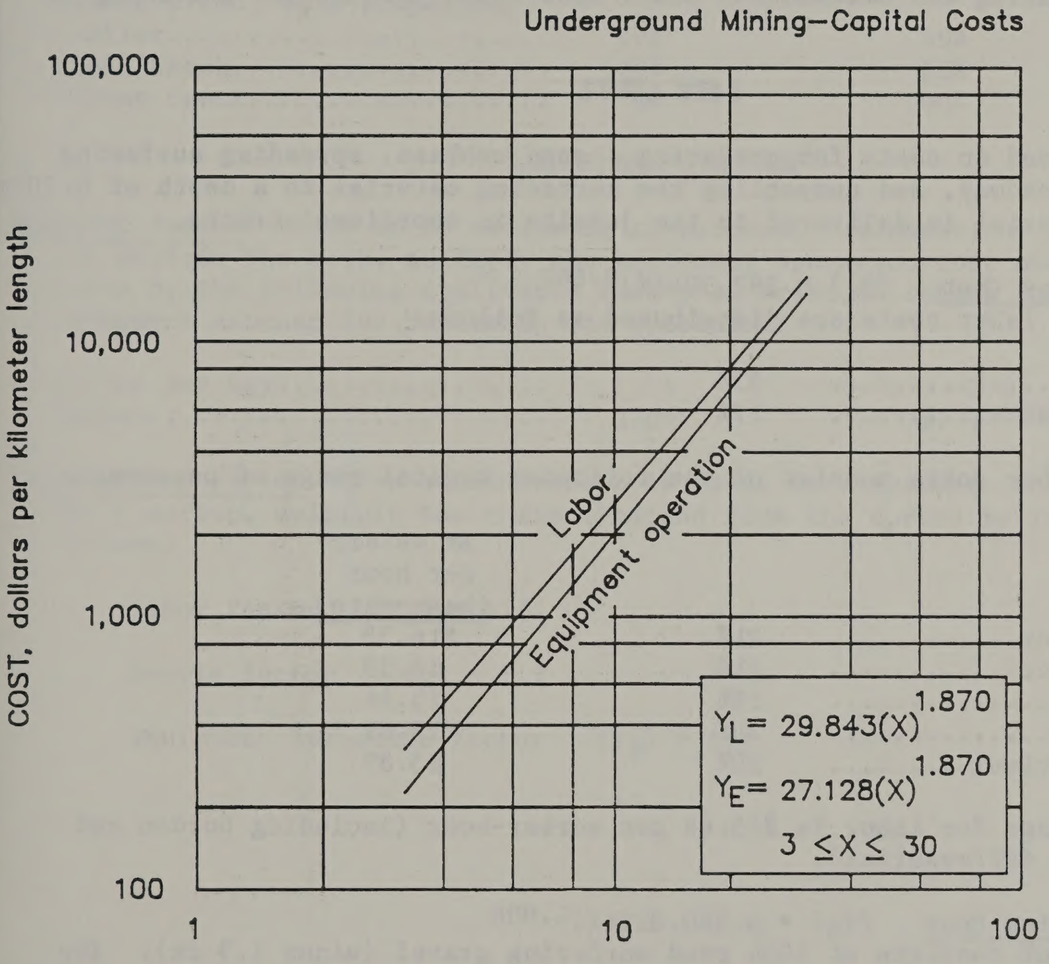
Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day.............	1	2	3
Factor.....................	1.94	1.71	1.63

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Equipment operation factor $(F_E) = 1.2$



4.2.7.1.3. Access roads
EXCAVATION

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.1.4. ACCESS ROADS
GRAVEL SURFACING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with gravel surfacing of access roads.

BASE CURVE

The curves are based on costs for preparing a road subbase, spreading surfacing material on the roadway, and compacting the surfacing material to a depth of 0.20 m. The surfacing material is delivered to the jobsite in suppliers' trucks.

(L) Labor Operating Cost $(Y_L) = 293.304(X)^{0.667}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Grader operator............	21%	$16.33
Roller operator............	21%	16.33
Dumpman....................	18%	13.86
Grade checker..............	20%	15.89
Water-truck driver.........	20%	15.89

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 6{,}880.012(X)^{1.006}$
The supply cost consists of 100% road surfacing gravel (minus 1.9 cm). The gravel, delivered and dumped on the roadbed by suppliers' trucks, costs $13.76 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 135.032(X)^{0.667}$
The equipment operation curve consists of 37% for repair parts, 51% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of

Motor grader...............	42%
Rubber-tired, self-propelled roller..........	19%
Water truck................	26%
Pickup truck...............	13%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Motor grader..................	45%	41%	14%
Rubber-tired, self-propelled roller......................	49%	40%	11%
Water truck...................	29%	55%	16%
Pickup truck..................	8%	90%	2%

ADJUSTMENT FACTORS

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

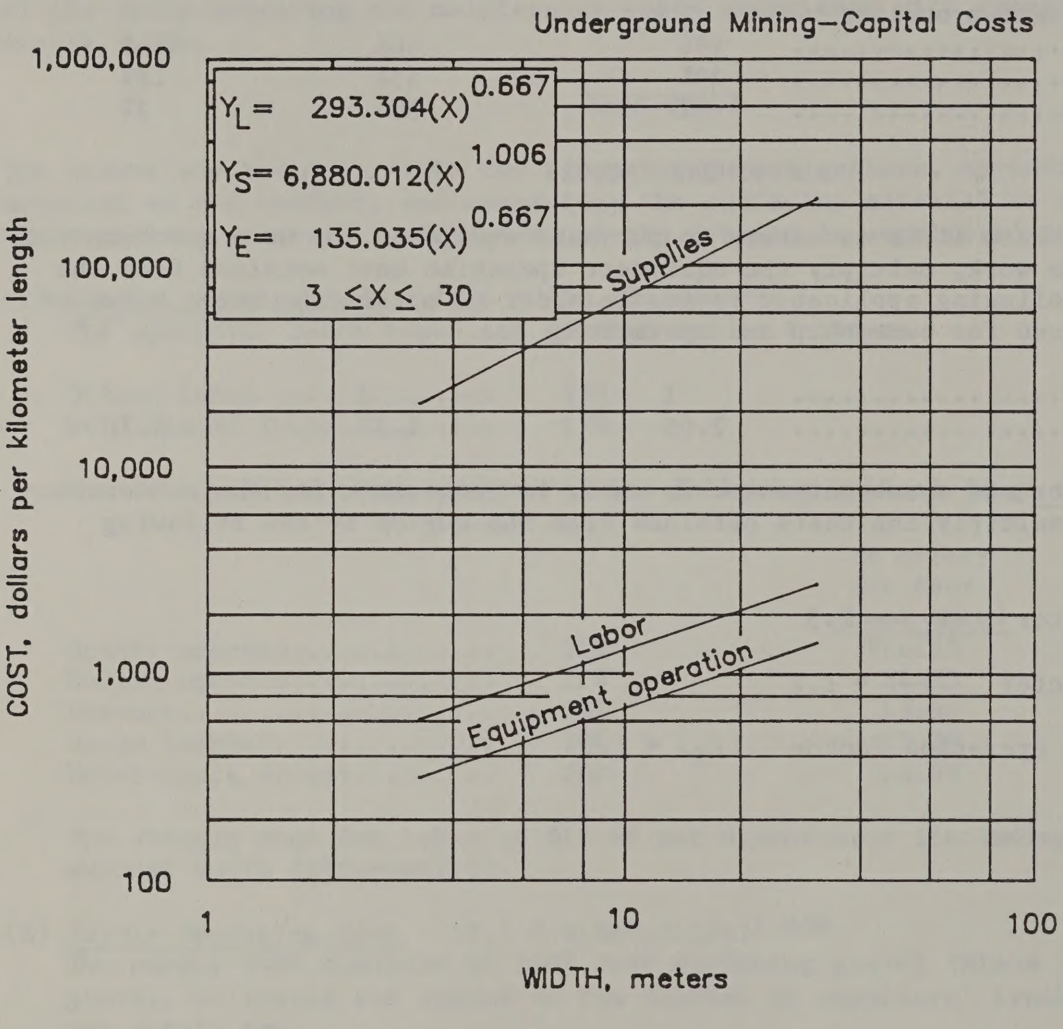
Shifts per day.................	1	2	3
Factor........................	2.05	1.79	1.70

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.5

Supply factor (F_S) = 1.2

Equipment operation factor (F_E) = 1.2



4.2.7.1.4. Access roads
GRAVEL SURFACING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.1.5. ACCESS ROADS
PAVING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with paving of access roads.

BASE CURVE

The curves are based on a paving operation for laying and compacting hot-mix asphalt concrete (purchased locally from a hot-mix plant) to a depth of 5.1 cm. Costs to produce an appropriate paving road base are covered in section 4.2.7.1.4., Gravel Surfacing.

(L) Labor Operating Cost $(Y_L) = 117.710(X)^{1.005}$
The operating labor costs are distributed as follows:

Direct Labor...............	80%
Maintenance Labor..........	20%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Paver operator.............	13%	$16.33
Roller operator............	26%	16.33
General laborer............	22%	13.86
Rear-dump truck driver.....	39%	15.89

The average wage for labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2{,}661.382(X)^{1.005}$
The supply cost consists of 100% asphalt concrete (minus 1.9-cm hot mix). The asphalt concrete, supplied by a local hot-mix plant, costs $26.37 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 68.436(X)^{1.005}$
The equipment operation curve consists of 32% for repair parts, 58% for fuel and lubrication, and 10% for tires.

The equipment operation curve consists of

Asphalt paver..............	20%
Rubber-tired, self-propelled roller....................	5%
Steel-wheeled, tandem roller	5%
Rear-dump trucks...........	64%
Pickup truck...............	6%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Asphalt paver...................	68%	32%	-
Rubber-tired, self-propelled roller........................	43%	51%	6%
Steel-wheeled, tandem roller	50%	50%	-
Rear-dump trucks................	22%	63%	15%
Pickup truck....................	8%	90%	2%

ADJUSTMENT FACTORS

Supply Factor The supplies cost should be adjusted for changes in the base asphalt-concrete price.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

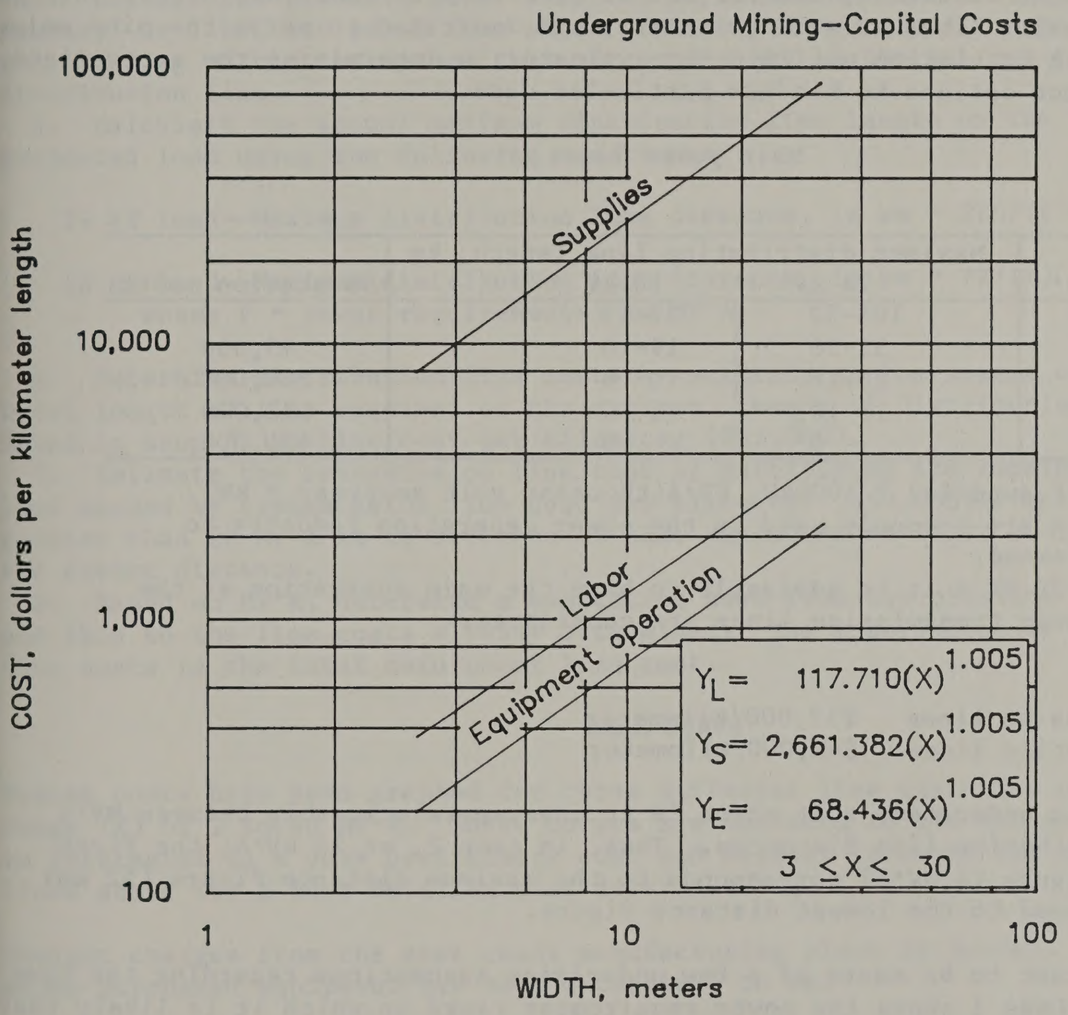
Shifts per day.................	1	2	3
Factor.........................	1.44	1.33	1.29

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



4.2.7.1.5. Access roads
PAVING

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.2. MAIN POWER LINES

If power is to be obtained from a local power company, it is generally necessary to construct new facilities to connect the mine site to the existing power line network. This cost is usually borne by the mine company that desires to receive the service. For shorter distances and lower maximum power loads this may simply entail extending existing, medium voltage (13-24 kV) distribution lines. To satisfy greater loads over longer distances, however, it is necessary to construct higher voltage (115 kV) transmission lines as well as substations dedicated to serve the mine solely. The following tabulation will aid the evaluator in determining the appropriateness of the various options to his/her particular case.

Main power lines

	Load	Maximum distribution line length, km		
Case	Range(MV·A)[1]	24 kV	13 kV	Substation costs
1...	2- 4	105-52	38-19	0
2...	4- 8	52-26	19-10	95,000
3...	8-12	26-18	10- 6	289,000
4...	12-20	18-10	6- 4	630,000
5...	20	0[2]	0	630,000

[1] MV·A(million volt amperes) = 1000kW; KV·A(thousand volt amperes) = kW
Both MV·A and KV·A are commonly used in the power generation industry to designate power demand.

[2] At greater than 20 MV·A it is advisable to have the main substation at the mine site, thus only transmission lines are considered.

LINE COSTS:

Transmission lines	$59,000/kilometer
Distribution lines	$42,000/kilometer

It is important to understand that there is an inverse relationship between MV·A and maximum distribution line distances. Thus, in case 2, at 24 kV·A, the first or lowest load figure (4 MV·A) corresponds to the maximum distance figure (52 km) and the highest load to the lowest distance figure.

It is also important to be aware of a few underlying assumptions regarding the five separate cases. Case 1 shows the power requirement range in which it is likely that existing distribution lines could supply the needed power. Thus there is no substation expense. The second and third cases assume that minor and major modifications of an existing substation will be required, respectively. They also assume that new line needed will originate from that modified substation. For cases 4 and 5 the large power requirements necessitate the construction of a completely new, dedicated substation. This facility will thus have to be fed by extending an existing high-voltage transmission line. In the instance of case 4, the site of the substation is as near the existing transmission line network as practicable; for case 5 the substation is assumed to be at the mine site.

The costs contained in this section assume that the power company that will be supplying the power will design and construct the line. Principal costs categories included are right-of-way purchase and clearing, access road construction, line and substation construction, permitting, and preconstruction design.

The procedure for determining the system cost and requirements are as follows:

1. Estimate the maximum power demand that the mine will require. If not available, an estimate of this value may be made by the techniques contained in the appropriate mine and beneficiation electrical system sections contained in this report. It is recommended that, for estimating purposes, horsepower and kW (or KV•A) be considered to be equivalent. Motor efficiencies as well as other system power losses generally account for much of the difference between the two units.
2. Contact the probable power supplier to determine the "nearest useable source," or likeliest point from which power may be obtained. Depending upon present loading within the system this may or may not be the nearest transmission or distribution line.
3. Calculate the actual maximum distribution line length on the basis of the projected load using the following equations:

24 kV load--Maximum distribution line distance, in km = 210/(P)

13 kV load--Maximum distribution line distance, in km = 77/(P)
where P = power requirements, in MV•A.

4. Determine distribution line costs by multiplying the lesser of either the total length of line required or the maximum length of distribution line as calculated in step 3, by line cost per kilometer ($42,000).
5. Estimate the transmission line cost by multiplying the remaining length of line needed by transmission line cost per kilometer ($59,000). Note that for greater than 20 MV•A it is recommended that transmission lines be installed for the entire distance.
6. Based on MV•A, determine a substation cost from the previous tabulation and add this to the line costs already determined. The combination of line and substation costs is the total main power line cost.

BASE CURVE

System costs have been graphed for three different line distances over the load range (X) of 2 to 40 MV•A. These curves are included to aid the manual user that is interested in a very preliminary cost and desires to avoid the procedure outlined above for a more detailed cost determination.

Freight charges from the east coast manufacturing plant to Denver, CO, for the major purchased equipment has been determined to be:

Transformer, mt..............................	$7,500
Oil breaker, 3 at 13 mt each..................	$9,600

All other equipment and materials are considered to be locally available in Denver, CO.

The total capital cost is based on single curves having power loads (X), in megavalt anperes. The curves are valid for power loads of 2 to 40 MV•A.

The capital cost derived from the curve is a combination of the following costs:

	Small (2 to 20 MV·A)	Large (20 to 40 MV·A)
Construction labor cost......	50%	47%
Construction supply cost.....	50%	37%
Purchased equipment cost.....	-	16%

The total 10 km main powerline capital cost is $(Y_{C\ 10\ KM\ LINE}) = 207{,}826.608(X)^{0.563}$ and is distributed as follows:

(L) Construction Labor cost $(Y_{L\ 10\ KM\text{-}SMALL}) = 103{,}913.304(X)^{0.563}$
(S) Construction Supply cost $(Y_{S\ 10\ KM\text{-}SMALL}) = 103{,}913.304(X)^{0.563}$

(L) Construction Labor cost $(Y_{L\ 10\ KM\text{-}LARGE}) = 97{,}678.506(X)^{0.563}$
(S) Construction Supply cost $(Y_{S\ 10\ KM\text{-}LARGE}) = 76{,}895.844(X)^{0.563}$
(E) Purchased Equipment cost $(Y_{E\ 10\ KM\text{-}LARGE}) = 33{,}252.257(X)^{0.563}$

The total 25km main powerline capital cost is $(Y_{C\ 25\ KM\ LINE}) = 644{,}990.250(X)^{0.370}$ and is distributed as follows:

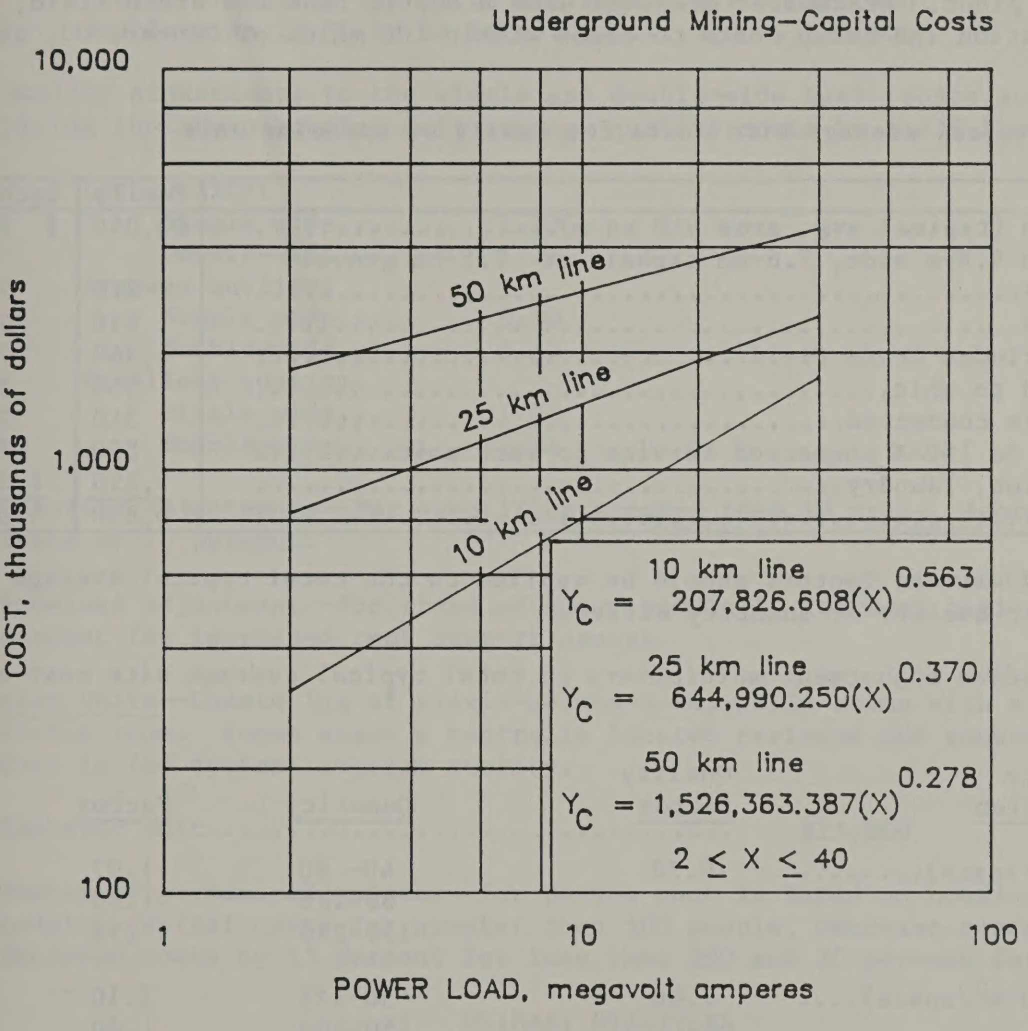
(L) Construction Labor cost $(Y_{L\ 25\ KM\text{-}SMALL}) = 322{,}495.125(X)^{0.370}$
(S) Construction Supply cost $(Y_{S\ 25\ KM\text{-}SMALL}) = 322{,}495.125(X)^{0.370}$

(L) Construction Labor cost $(Y_{L\ 25\ KM\text{-}LARGE}) = 303{,}145.418(X)^{0.370}$
(S) Construction Supply cost $(Y_{S\ 25\ KM\text{-}LARGE}) = 238{,}646.392(X)^{0.370}$
(E) Purchased Equipment cost $(Y_{E\ 25\ KM\text{-}LARGE}) = 103{,}198.440(X)^{0.370}$

The total 50km main powerline capital cost is $(Y_{C\ 50\ KM\ LINE}) = 1{,}526{,}363.387(X)^{0.278}$ and is distributed as follows:

(L) Construction Labor cost $(Y_{L\ 50\ KM\text{-}SMALL}) = 763{,}181.694(X)^{0.278}$
(S) Construction Supply cost $(Y_{S\ 50\ KM\text{-}SMALL}) = 763{,}181.694(X)^{0.278}$

(L) Construction Labor cost $(Y_{L\ 50\ KM\text{-}LARGE}) = 717{,}390.792(X)^{0.278}$
(S) Construction Supply cost $(Y_{S\ 50\ KM\text{-}LARGE}) = 564{,}754.453(X)^{0.278}$
(E) Purchased Equipment cost $(Y_{E\ 50\ KM\text{-}LARGE}) = 244{,}218.142(X)^{0.278}$



4.2.7.2. Main power lines

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.7. INFRASTRUCTURE

4.2.7.3. TOWNSITE

The following housing costs are for a typical average quality park based on using trailers or manufactured 'mobile home' housing containing between 150 and 200 units. Costs are quoted per individual housing unit. Costs are factored by using the Bureau of Labor Statistics Industrial Materials Cost Index. Site costs do not include land site acquisition, construction of utility trunk lines to the site, or a wastewater treatment plant. Wastewater disposal uses a septic tank and drain field; however, transportation and setup costs to areas within 100 miles of Denver, CO, are included.

Typical average site costs for family or bachelor unit

	Family	Bachelor
Site preparation (typical avg. area 410 sq m)	$1,050	$ 320
Streets (7.9- to 9.8-m wide, 7.6-cm asphalt or 7.5-cm gravel edged or curbed)	810	270
Patios and walks	610	200
Septic tank, includes drain field	1,360	750
Water, connected to unit	550	550
Gas, low pressure connected	310	310
Electrical, 80- to 150-A connected service to each unit	890	890
Office, recreation, laundry	1,250	1,250
Total	6,830	4,540

The following adjustment factors should be applied to the total typical average site cost where either quality or quantity differs.

Site preparation adjustment multipliers to total typical average site cost are as follows:

Quality description	Quality factor	Quantity	Factor
Low ($300 m^2$/space)	0.70	40- 80	1.07
		80-125	1.00
		150-250	.92
Average ($410 m^2$/space)	1.00	50-125	1.10
		150-200	1.00
		250-300	.95
Good ($520 m^2$/space)	1.30	50-150	1.10
		175-200	1.00
		250-350	.97

In addition, the following accessories may also be required:

Skirting at base of trailer....................	$620.00
Landing and steps..............................	360.00
Canopies over landings.........................	550.00
Air conditioning--using existing heater.......	840.00

HOUSING UNITS

Family Units--With living, dining, kitchen, bath, and sleeping facilities for two adults and two to four children. Cost is for typical average quality.

Single-wide (4.27 by 19.50 m)............	$15,400
Double-wide (7.31 by 14.63 m)............	26,400

Quality adjustments to the single and double-wide basic costs are made by multiplying the above housing unit average quality costs by the following factors:

Low quality:	
Single wide......	1.12
Double-wide......	1.16
Average quality:	
Single wide......	0.90
Double-wide......	0.87
Excellent quality:	
Single wide......	1.25
Double-wide......	1.34

Quantity adjustments--For quantities greater than 10 units, decrease overall costs by 10 percent.

Snowload adjustment--For areas of heavy snowfall, increase basic unit costs 5 percent for increased roof support design.

Bachelor Units--Consisting of single-person motel-style rooms with a kitchen and dining room. Rooms share a centrally located restroom and shower facility. Cost is for typical average quality.

Bachelor unit.................................	$15,000

Number of persons adjustment--Per person cost is based on housing 400 personnel. Lodging capital costs for greater than 500 people, decrease costs by 10 percent. Increase costs by 15 percent for less than 300 and 20 percent for less than 200.

PRIMARY UTILITIES

Electrical, cost per linear meter:	
Main overhead electric powerlines...........	$26.32
Lateral overhead lines......................	$8.25
Water, cost per linear meter:	
Main, 15.24 cm plastic (add or deduct $5.75 per 2.54 cm diam).........................	$35.80
Lateral, 2.54 cm............................	$17.22

4.2.7.4.1. WASTE WATER TREATMENT CLARIFICATION

Clarification capital cost is for the acquisition and installation of equipment for water clarification and softening by precipitation and/or coagulation. The all metal solids-contact clarifier combines into one operation--quick mixing, flocculation, clarification, and sludge thickening. The unit will selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, hardness, alkalinity, taste, and odor. The cost curve is based on clarifiers ranging in diameter from 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2).

BASE CURVES

Total cost is based on a single cost curve having a tank diameter of (X) in meters. The curve includes all costs associated with acquisition and installation of concrete pad, clarifier structure, and control-monitor equipment for sludge level and sludge density control.

The total clarification capital cost derived from the curve is a combination of the following costs:

Construction labor cost.......	19%
Construction material cost....	5%
Purchased equipment cost......	76%

The total clarification capital cost is $(Y_C) = 15{,}631.070(X)^{0.991}$ and is distributed as follows:

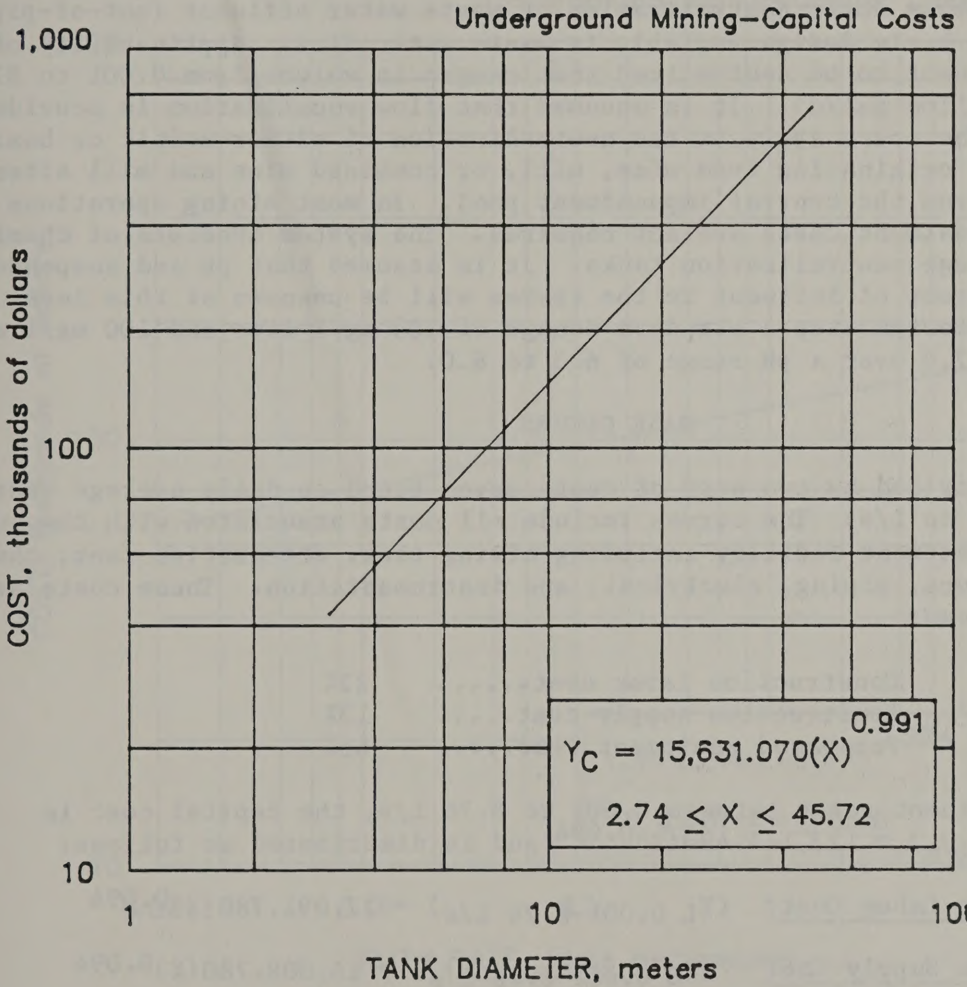
(L) Construction Labor Cost $(Y_L) = 2{,}969.910(X)^{0.991}$

(S) Construction Supply Cost $(Y_S) = 781.550(X)^{0.991}$

(E) Purchased Equipment Cost $(Y_E) = 11{,}879.610(X)^{0.991}$

NOTE:- Sizing of clarifier is based on one principal parameter-- rise rate--the vertical velocity of the stream through the clarifier. If the diameter or cross-sectional area of the clarifier is unknown, and the feed flow rate is known and the rise rate is assumed to be 0.015 m/min, then the diameter (D), or equivalent cross-sectional area, of the clarifier can be estimated with the equation:

Clarifier diameter $(D) = 1.128[(Q)/(R)]^{0.500}$
where R = rise rate, in meters per minute,
and Q = design flow rate, in cubic meters per minute.



4.2.7.4.1. Wastewater treatment
CLARIFICATION

4.2.7.4.2. WASTEWATER TREATMENT NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The capital cost curves cover neutralization of waste water effluent (out-of-pipe) when required. The basic design variable is waste water flow. Applicability of the curves are for effluent to be neutralized that ranges in volume from 0.001 to 876 1/s (22.8 to 20 million gal/d). It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/1 lime and 100 mg/1 acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

Total costs are described by two sets of cost curves based on daily average waste water flow rate (X) in L/s. The curves include all costs associated with the construction of the treatment facility including mixing tank, attenuation tank, chemical storage, agitators, piping, electrical, and instrumentation. These costs are distributed as follows:

Construction labor cost......	22%
Construction supply cost.....	13%
Purchased equipment cost.....	65%

For waste water effluent rates between 0.001 to 8.76 L/s, the capital cost is $(Y_{C\ 0.001\text{-}8.76\ L/s}) = 123{,}144.490(X)^{0.094}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ 0.001\text{-}8.76\ L/s}) = 27{,}091.780(X)^{0.094}$

(S) Construction Supply Cost $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 16{,}008.780(X)^{0.094}$

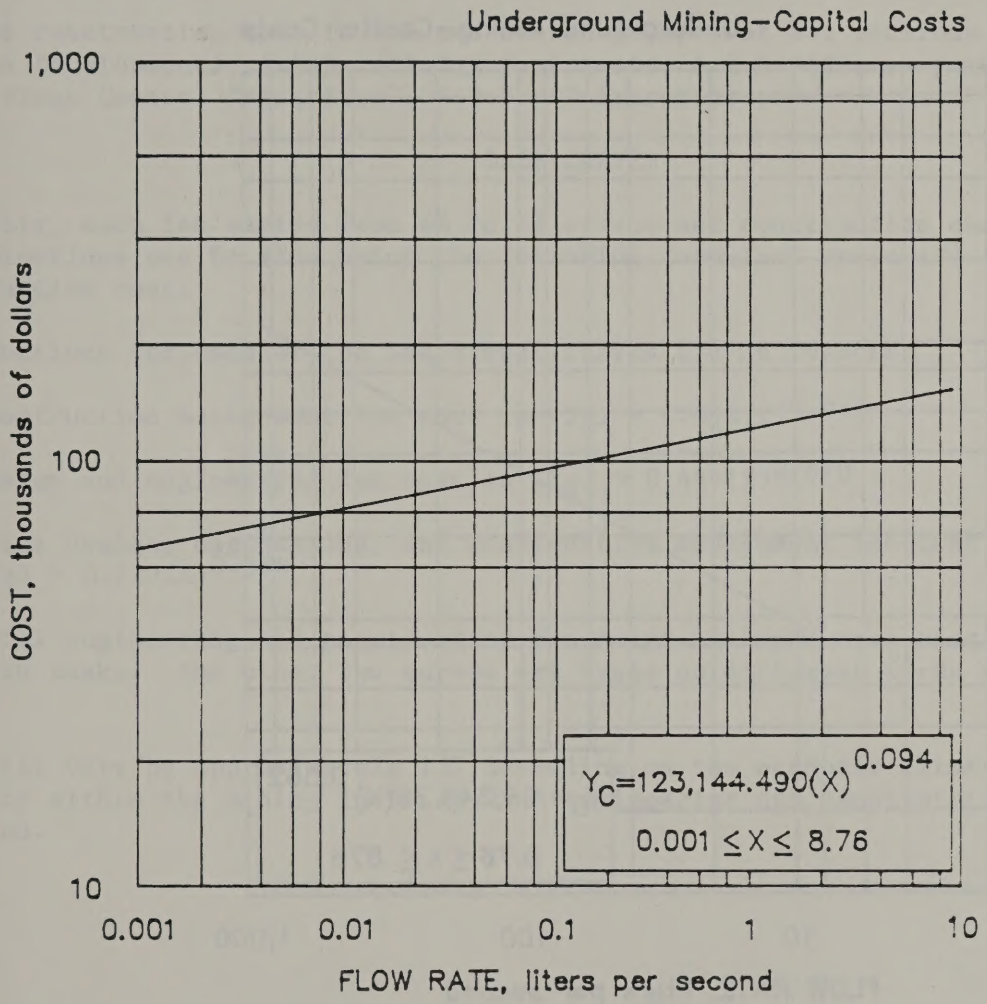
(E) Purchased Equipment Cost $(Y_{E\ 0.001\text{-}8.76\ L/s}) = 80{,}043.930(X)^{0.094}$

For waste water effluent rates between 8.76 to 876 L/s, the capital cost is $(Y_C\ 8.76\text{-}876\ L/s) = 26{,}346.39(X)^{0.562}$ and is distributed as follows:

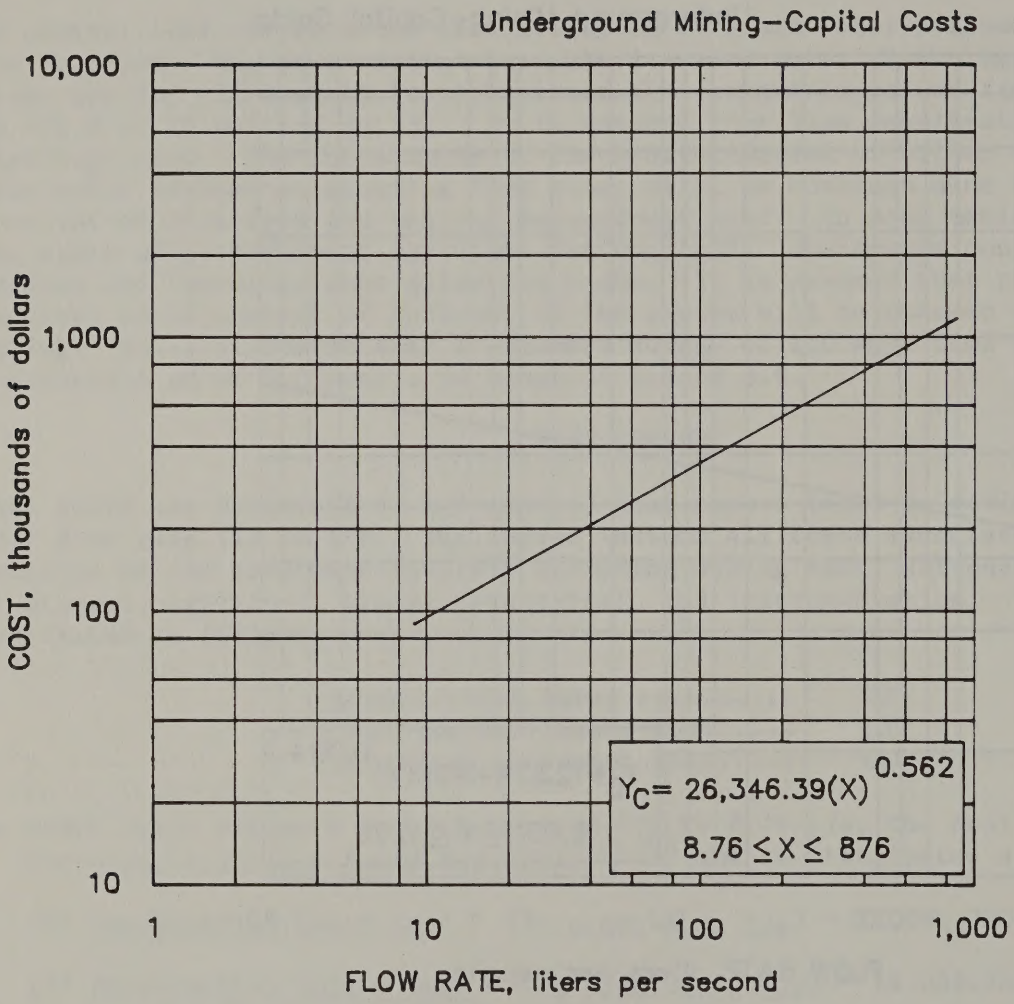
(L) Construction Labor Cost $(Y_L\ 8.76\text{-}876\ L/s) = 5{,}796.21(X)^{0.562}$

(S) Construction Supply Cost $(Y_S\ 8.76\text{-}876\ L/s) = 3{,}425.03(X)^{0.562}$

(E) Purchased Equipment Cost $(Y_E\ 8.76\text{-}876\ L/s) = 17{,}125.15(X)^{0.562}$


Underground Mining—Capital Costs

4.2.7.4.2.a Wastewater treatment
NEUTRALIZATION



Underground Mining—Capital Costs

4.2.7.4.2.b Wastewater treatment
NEUTRALIZATION

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.8. ENGINEERING AND CONSTRUCTION MANAGEMENT FEES

Fees vary according to access, location, topography, shape of ore body, type of mineral extracted, and type of entry to the mine. The curves are based on percentage of net constructed cost. The approximate correlations between design engineering and construction costs are illustrated in these curves. The curves for design engineering, construction management, and total engineering and construction management are based on data supplied through interviews in 1983 and 1984 with several major mining engineering and construction firms.

The net construction cost is the sum of the group cost for sections 4.2.1. (Preproduction Development), 4.2.3. (Mining Equipment), 4.2.4. (Trans- portation), 4.2.5. (Mine Plant General Operations), 4.2.7. (Infrastructure).

BASE CURVES

Generally, each fee varies from 4% to 6% of the net construction cost. Actual cost determinations can be made using the following formulas, where (X) is the total net construction cost:

The equations for each of the individual curves are as follows:

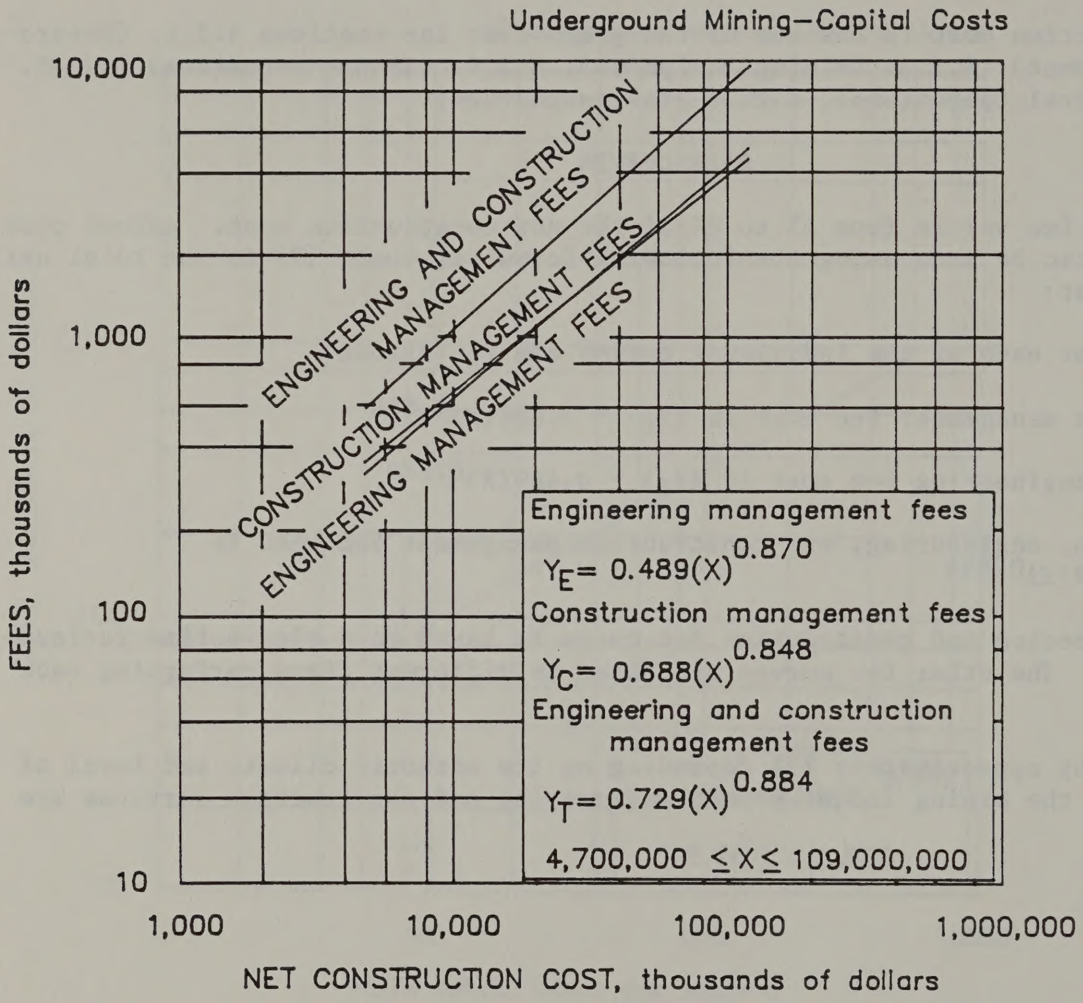
The construction management fee cost is $(Y_C) = 0.688(X)^{0.848}$

The design and engineering fee cost is $(Y_E) = 0.489(X)^{0.870}$

The total design, engineering, and construction management fee cost is $(Y_T) = 0.729(X)^{0.884}$

The total engineering and construction fee curve is based on a single firm performing both tasks. The other two curves are based on different firms performing each task.

Fees will vary by approximately 15% depending on the economic climate and level of activity within the mining industry when engineering and construction services are required.



4.2.8. Engineering and construction management fees

4.2.9. WORKING CAPITAL

Working capital is the cash required to sustain a mining and/or milling operation between mining the ore and receiving revenue from its sale. It is the capital required to meet out of pocket expenses, such as payroll, equipment operation, utilities, and administrative operating costs. In aggregate, these are the total operating costs for the operation during the designated time period. Because this time lag persists; that is, monies received in payment for September's production are reinvested in material and supplies to produce ore in November or December, a continuing account must be maintained as long as the operation is active.

A reasonable estimate of this lag period is dependent upon the type of operation under study. For operations that must send concentrates to a smelter, working capital is estimated as 10 weeks of operating, administrative and transportation costs. This estimate includes 2 weeks for transportation by rail to the smelter as well as 2 months for the smelter to make payment. By far the majority of precious and nonferrous metal producers can be thus classified.

Less working capital, 6 weeks of operating and administrative costs, is required for mines that market their product directly or that have vertically integrated processing facilities (i.e., same company owns smelter and/or refinery or company sells the end product).

Adjustments should be considered if the transportation time to the smelter or smelter settlement time varies from assumed values. Adjustments should also be made to mine working capital if large mined ore stockpiles are maintained between the mining and milling stages, as this also advances the final settlement date.

For mines with mills that do not ship concentrates on a regular schedule because of remoteness and/or do not operate year-round, working capital should be increased appropriately.

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.2. CORE DRILLING

Core drilling requirements vary considerably from mine to mine. For steeply dipping veins that require continuing development, as mining progresses downward, the amount drilled is relatively high; for near surface, flat-lying ore bodies for which grade and ore extent are easily determined drilling requirements will be minimal following initial exploration and development. For small to medium sized vein mines, 500 to 2,000 mtpd, typical drilling requirements range from 1,000 to 5,000 m/yr; for large bulk operations, 5,000 to 50,000 mtpd, such as block caving mines, 5,000 m/yr and greater are more typical. The evaluator should determine the approximate value appplicable in the instance under study.

Surface rotary or diamond drills may also used for assay control and ore body definition. This is especially true if the ore body is relatively flat lying and near surface. If the evaluator feels that this is characteristic of the case under study, the appropriate surface mining section should be consulted for pertinent costs.

BASE CURVES

The total cost per day is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a drilling rate (X), in meters per day, times the cost per meter. Costs are based on an operating schedule of one shift per day.

The core drilling costs in this section are predicated upon utilizing a diamond drill capable of penetrating to 300 meters, an AWG bit (hole size is 4.80 cm or 1.89 in), and an average penetration rate of 12.2 m per shift. All costs are per meter drilled and considers move time and downtime. Total costs for an in-house drilling program can be estimated as $44.75 per meter.

(L) Labor Cost $(Y_L) = (\$21.38/\text{m})(X)$
The operating labor costs are distributed as follows:

Direct labor................	97%
Maintenance labor..........	3%

The operating labor costs are based on straight days pay, drilling bonuses have been ignored, and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Drillers....................	50%	$18.11
Drillers helper.............	50%	13.66

Average wage for labor is $15.89 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = (\$20.67/m)(X)$
The supply cost consists of 70% drill bits, drill rods, and core barrel assembly parts, 7% electrical power, and 23% miscellaneous items.

(E) Equipment Cost $(Y_E) = (\$2.70/m)(X)$
The equipment operating cost consists of 48% for parts, 13% for lubrication, and 39% for miscellaneous costs for drill and pump equipment.

ADJUSTMENT FACTORS

Cutout Costs In many instances it is necessary to blast cutouts for a drilling station to ensure that the drilling crew does not impede traffic along the drifts. This is typically accomplished by a minimum of two rounds in either rib. This additional charge should be taken into consideration when determining the total cost of the drilling program. For appropriate costs refer to the drifting section that would apply.

Contractor Factor It has become standard within the industry for the drilling to be done by contractor. To adjust for this eventuality, the evaluator should increase the labor cost by 38%. Equipment operation and supply costs will not be affected directly, however; all three categories (equipment operation, supplies, and adjusted labor) should be increased by an additional 35% for indirect field, local, and national overhead, and contractor profit charges. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.86$

Supply factor $(F_S) = 1.35$

Equipment operation factor $(F_E) = 1.35$

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.3. SINKING SHAFTS

The total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 40 m^2, with average advances of 1.9 m/d in the smaller shafts and 1.3 m/d overall in the larger shafts, operating three shifts per day. The curves are based on circular shafts with concrete lining. Total daily cost is the cost per meter advance times the daily advance rate.

Services installed in the shaft include guides, manways, air, water and vent lines, and signal lines. Sinking is considered to be done with a sinking headframe. Costs for permanent hoisting facilities are included in section 4.2.3.1. (Hoisting Facilities).

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 615.595(X)^{0.542}$
The operating labor costs are distributed as follows:

Direct labor................	84%
Maintenance labor...........	16%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	34%	$18.44
Helpers.....................	22%	15.09
Support.....................	44%	17.04

Average wage for labor is $16.35 per worker-hour (including burden and average shift differential)

(S) Supply Operating Cost $(Y_S) = 182.051(X)^{0.558}$
The supply cost consists of 21% explosives, 34% steel items, 38% miscellaneous items, 6% electricity, and 1% timber. Supplies include drill bits and steel, powder, caps, timber, hanging rods, vent line, compressed air pipe, pump line, water line, concrete line, blasting lines, and bell cord.

(E) Equipment Operating Cost $(Y_E) = 681.476(X)^{0.407}$
The equipment operating cost consist of 88% for repair parts, 7% for fuel and lubrication, and 5% for tires (tires used on topside crane and loader servicing the shaft sinking). The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for drills, fans, muckers, and other equipment used to sink the shaft.

ADJUSTMENT FACTORS

Rock Hardness Factor Shaft sinking productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

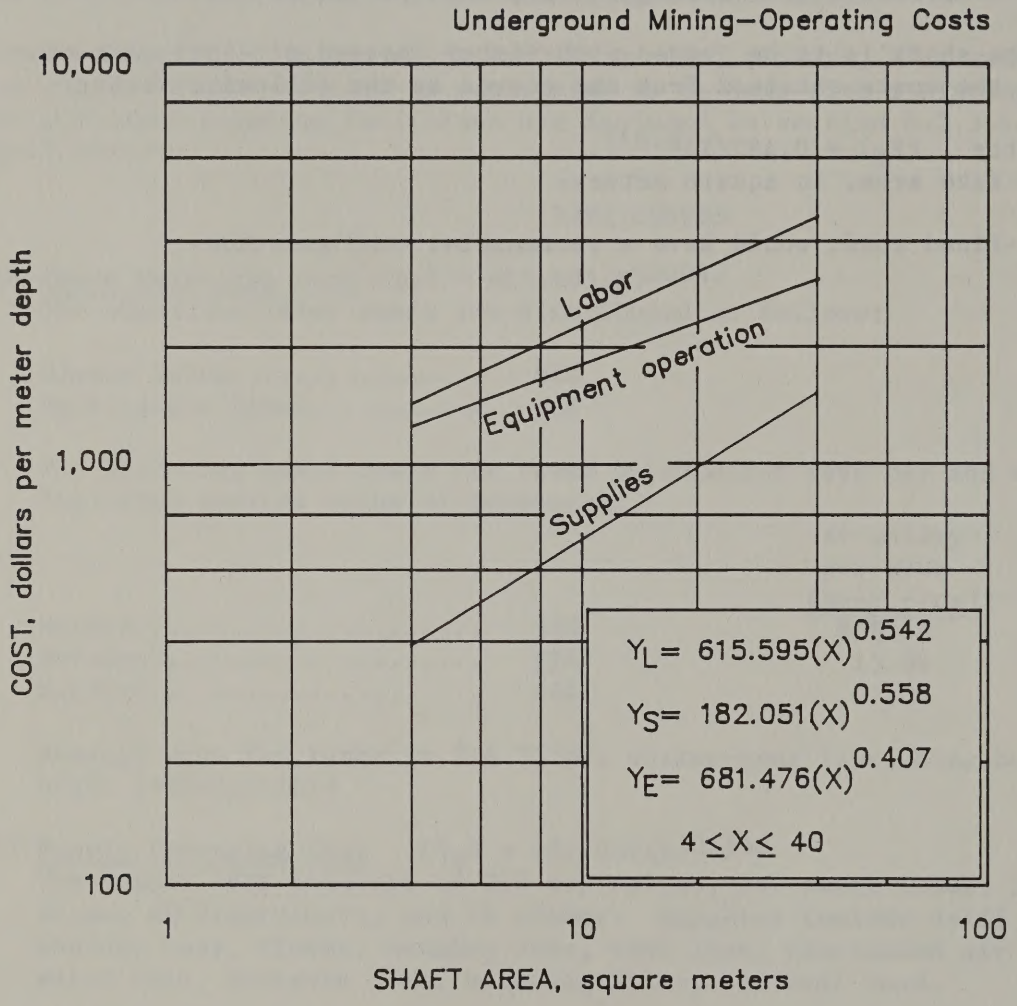
Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch.

Timber Factor If the shaft is to be lagged with timber instead of lined with concrete, multiply the costs obtained from the curves by the following factor:

Timber factor $(F_T) = 0.482(X)^{0.077}$.
where: X = face area, in square meters.

Assume a timber-lined shaft would have a rectangular configuration.



5.2.1.3. Sinking shafts

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.1. DRIFT DEVELOPMENT
SMALL DRIFTS FOR RAIL HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 2 to 3 m/d, with productivity averaging 0.39 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with 3.0-in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, track laying, lunch, and travel. Muck is loaded into 2.0- or 3.0-yd^3 development cars using an overshot mucker. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 3 and 12 m^2, operating two shifts per day. The daily operating cost is the product of meters of drift driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 79.926(X)^{0.764}$
The operating labor costs are distributed as follows:

Direct labor................	95%
Maintenance labor...........	5%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (3 to 6 m^2)	Large (6 to 12 m^2)	Av salary per hour (base rate)
Miners......................	90%	83%	$18.31
Helpers.....................	-	11%	13.86
Motor operators.............	10%	6%	16.09

Average wage for labor is $17.56 per worker-hour (including burden and average shift differential).

S) Supply Operating Cost $(Y_S) = 73.283(X)^{0.602}$
The supply cost consists of 44% steel items, 23% explosives, 10% drill bits and steel, 10% ventilation materials, 5% material waste, 4% timber, 3% ballast, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rockbolts, water pipe, compressed air pipe, electricity, steel rail, ties, ballast, ventilation tubing, and material waste.

The equipment operating cost consists of 73% for maintenance and overhaul parts, 11% for fuel, 8% for ground engaging components, and 8% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and ground engaging components. Equipment used in drifting includes jacklegs, overshot muckers, ore cars, jackhammers, locomotives, and auxiliary fans.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known,or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.10$

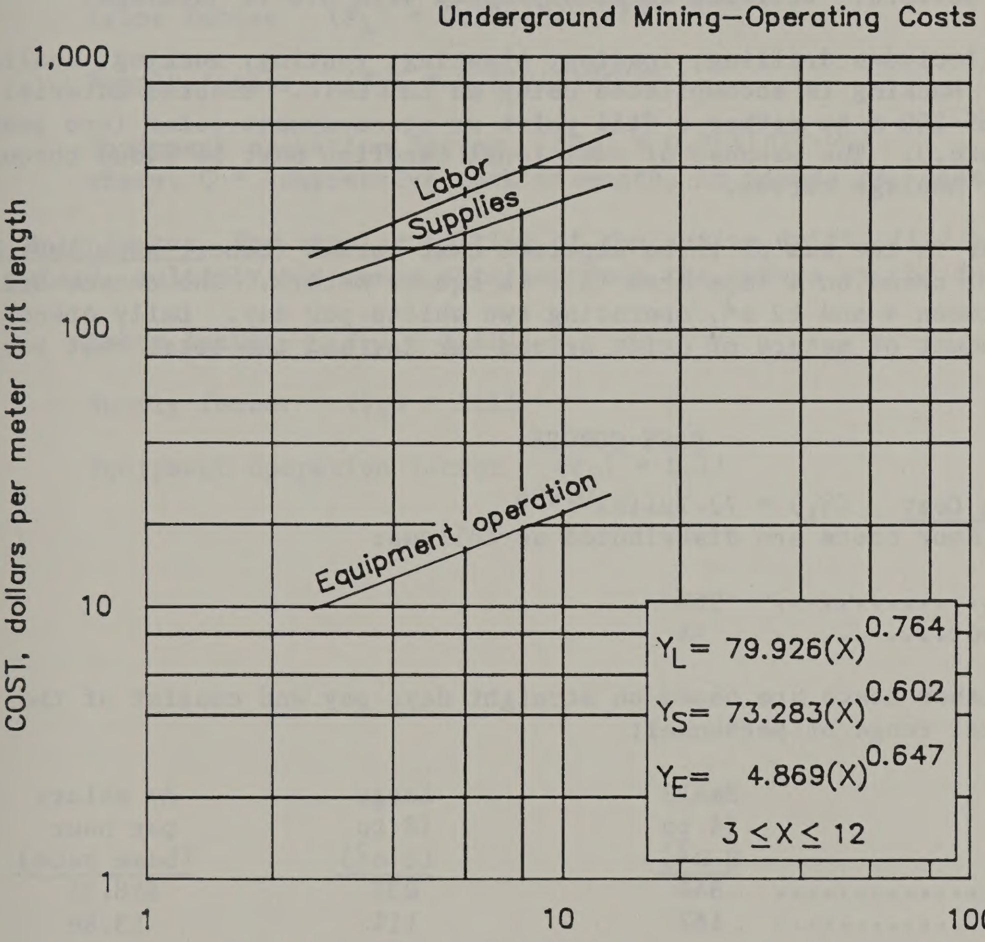
Equipment operation factor $(F_E) = 1.16$

Timbering Factor If the drifts require timbering, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.30$

Supply factor $(F_S) = 1.39$

These factors will account for standard cap and post timbering plus lagging for the entire length of the drift.



5.2.1.4.1. Drift development
SMALL DRIFTS FOR RAIL HAULAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.2. DRIFT DEVELOPMENT SMALL DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with average rock hardness, abrasiveness and standing characteristics are assumed. Advance rates range from 2.4 to 3.6 m/d, with productivity averaging 0.49 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with 3.0-in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using an LHD unit. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 12 m^2, operating two shifts per day. Daily operating cost is the product of meters of drift driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 72.721(X)^{0.685}$
The operating labor costs are distributed as follows:

Direct labor................	96%
Maintenance labor..........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (4 to 8 m^2)	Large (8 to 12 m^2)	Av salary per hour (base rate)
Miners......................	84%	83%	$18.31
Helpers.....................	16%	11%	13.86
LHD operators..............	-	6%	16.53

Average wage for labor is $17.30 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 43.313(X)^{0.687}$
The supply cost consists of 33% steel items, 33% explosives, 15% ventilation materials, 13% drill bits and steel, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rockbolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 1.360(X)^{1.188}$
The equipment operating cost consists of 64% for maintenance and overhaul parts, 18% for tires, 13% for fuel, and 5% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jacklegs, LHD's, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

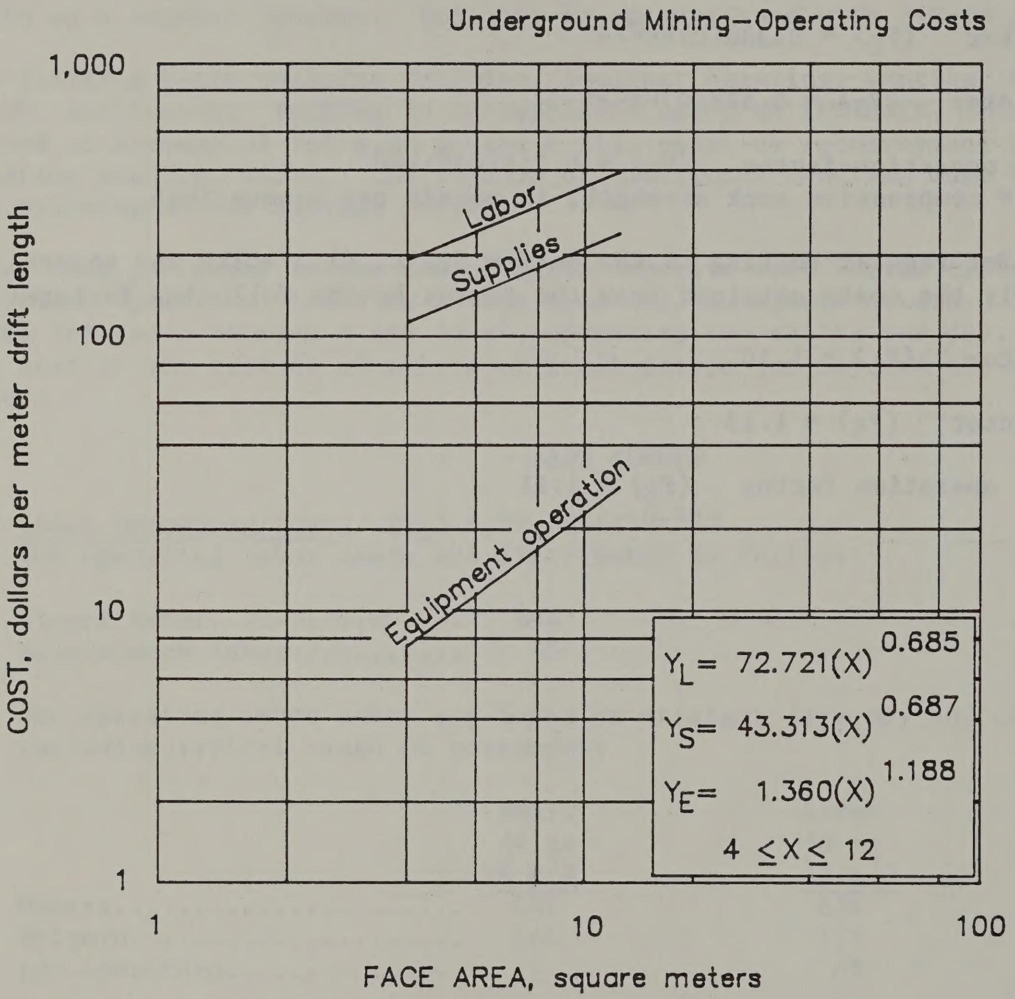
Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch.

Rock Bolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.10$

Supply factor $(F_S) = 1.15$

Equipment operation factor $(F_E) = 1.11$



5.2.1.4.2. Drift development
SMALL DRIFTS FOR RUBBER—TIRED HAULAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.3. DRIFT DEVELOPMENT
MEDIUM DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with face areas between 6 and 20 m^2. Average rock hardness, abrasiveness, and standing characteristics are assumed. Advance rates range from 5.4 to 6.0 m/d, with productivity averaging 0.71 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rock bolts on a regular pattern. Drilling is accomplished with two- or three-boom jumbos.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using an LHD unit. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 6 and 20 m^2, operating two shifts per day. Daily operating cost is the product of meters of drift driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 86.960(X)^{0.349}$
The operating labor costs are distributed as follows:

Direct labor................	93%
Maintenance labor...........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (6 to 13 m^2)	Large (13 to 20 m^2)	Av salary per hour (base rate)
Miners.....................	69%	67%	$18.31
Helpers....................	21%	20%	13.86
LHD operators..............	10%	7%	16.53
Utility workers............	-	6%	16.98

The average wage for labor is $17.21 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 27.390(X)^{0.855}$
The supply cost consists of 53% steel items, 29% explosives, 12% ventilation materials, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, prima- cord, rockbolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost (Y_E) = $4.497(X)^{0.684}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 24% for tires, 14% for fuel, and 5% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jumbo-mounted drifters, LHD's, jacklegs, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1, in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor (F_L) = $0.388(C)^{0.093}$

Supply factor (F_S) = $0.579(C)^{0.054}$

Equipment operation factor (F_E) = $0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch

Rockbolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.08

Supply factor (F_S) = 1.14

Equipment operation factor (F_E) = 1.42

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.03

Supply factor (F_S) = 1.24

Equipment operation factor (F_E) = 1.15

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.64

Supply factor (F_S) = 1.72

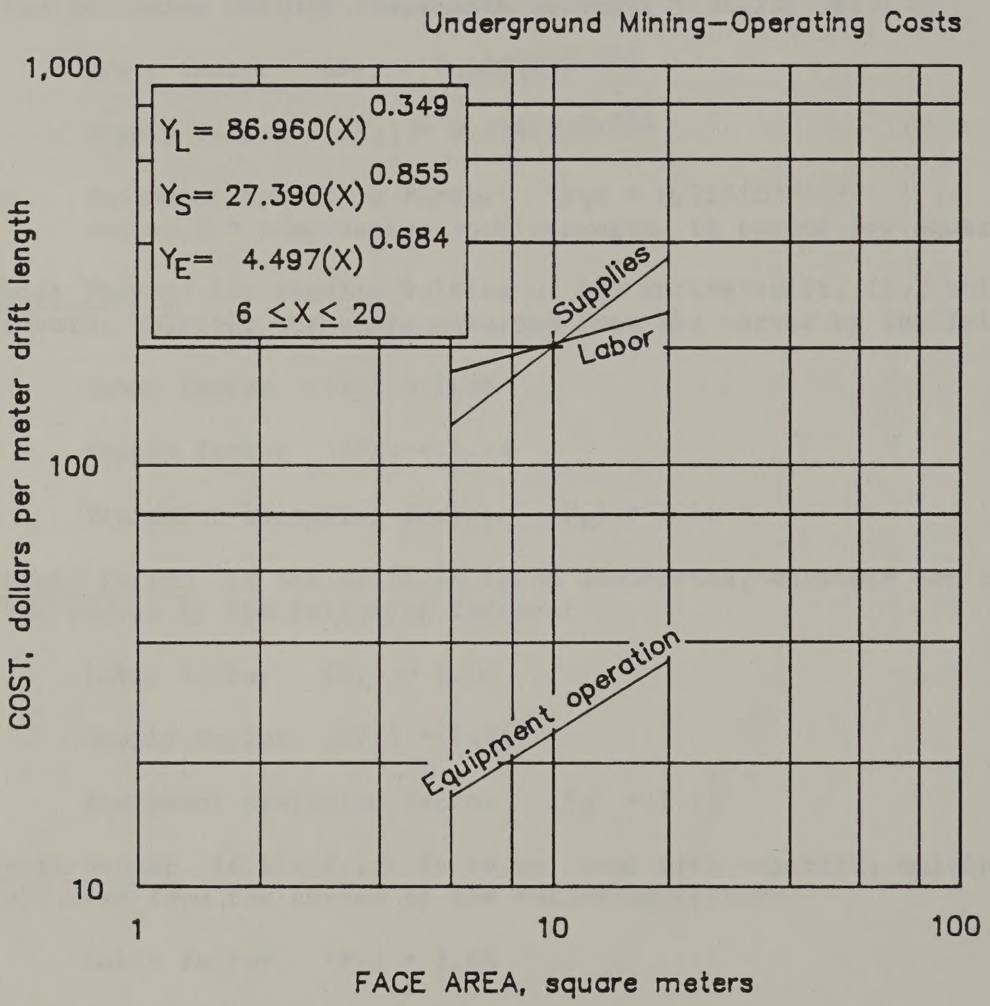
Equipment operation factor (F_E) = 2.26

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.37$

Supply factor $(F_S) = 2.47$

Equipment operation factor $(F_E) = 1.19$



5.2.1.4.3. Drift development
MEDIUM DRIFTS FOR RUBBER—TIRED HAULAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.4. DRIFT DEVELOPMENT LARGE DRIFTS FOR RAIL HAULAGE

Costs derived from these curves apply to drifts with face areas between 8.0 and 25.0 m^2. Average rock hardness, abrasiveness, and standing characteristics are assumed. Advance rates range from 5.0 to 6.8 m/d, with productivity averaging 0.57 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rockbolts on a regular pattern. Drilling is accomplished with 3.0-in jacklegs.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, track laying, lunch, and travel. Muck is loaded into 6.0- to 10.0-yd^3 development cars using an overshot mucker. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 8 and 25 m^2, operating two shifts per day. Daily operating cost is the product of meters of drift driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 27.037(X)^{0.857}$
The operating labor costs are distributed as follows:

Direct labor................	90%
Maintenance labor...........	10%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (8 to 16 m^2)	Large (16 to 25 m^2)	Av salary per hour (base rate)
Miners.....................	73%	68%	$18.31
Helpers....................	12%	17%	13.86
Utility workers............	8%	-	16.98
Track workers..............	-	9%	16.53
Motor operators............	7%	6%	16.09

The average wage for labor is $17.34 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 63.689(X)^{0.693}$
The supply cost consists of 53% steel items, 19% explosives, 10% drill bits and steel, 8% ventilation materials, 5% material waste, 3% timber, 1% ballast, and

1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rockbolts, water pipe, compressed air pipe, electricity, steel rail, ties, ballast, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 1.437(X)^{1.056}$
The equipment operating cost consists of 83% for maintenance and overhaul parts, 9% for ground engaging components, 4% for fuel, and 4 percent for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and ground engaging components. Equipment used in drifting includes jumbos, overshot muckers, ore cars, jacklegs, jackhammers, locomotives, scissor lifts, rail tampers, roof bolters, and auxiliary fans.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch.

Rockbolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.02$

Supply factor $(F_S) = 1.09$

Equipment operation factor $(F_E) = 1.23$

Dual Track Factor To account for two sets of tracks in the drift (drifts greater than 16 m^2 only) multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.11$

Supply factor $(F_S) = 1.26$

Equipment operation factor $(F_E) = 1.17$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.02$

Supply factor $(F_S) = 1.16$

Equipment operation factor $(F_E) = 1.15$

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.52

Supply factor (F_S) = 1.81

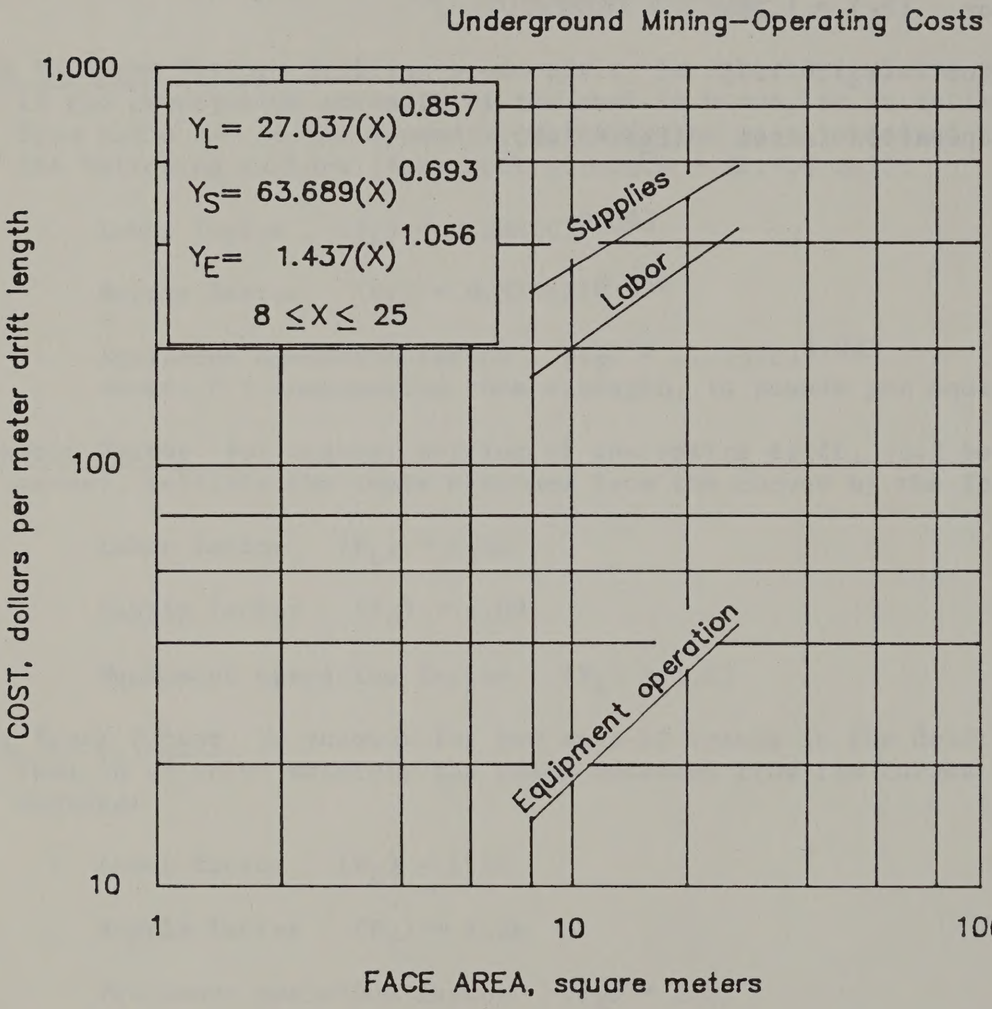
Equipment operation factor (F_E) = 2.14

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.29

Supply factor (F_S) = 1.95

Equipment operation factor (F_E) = 1.10



5.2.1.4.4. Drift development
LARGE DRIFTS FOR RAIL HAULAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.5. DRIFT DEVELOPMENT LARGE DRIFTS FOR RUBBER-TIRED HAULAGE

Costs derived from these curves apply to drifts with assumed average rock hardness, abrasiveness, and standing characteristics. Advance rates range from 2.3 to 2.7 m/d, with productivity averaging 0.55 m per worker-shift. It has been assumed that 10% of the drift will require support consisting of 6-ft expansion shell rockbolts on a regular pattern. Drilling is accomplished with two- or three-boom jumbos.

The drifting cycle includes drilling, loading, blasting, venting, mucking, scaling, lunch, and travel. Mucking is accomplished using front-end loaders and trucks. Blasted material is hauled an average of 200 m to either a fill point or reconveyance point (ore pass, hoisting station, etc.). The expense of additional handling must be added through the hoisting and/or haulage curves.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 20 and 50 m^2, operating two shifts per day. Daily operating cost is the product of meters of drift driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 43.360(X)^{0.542}$
The operating labor costs are distributed as follows:

Direct labor................	91%
Maintenance labor...........	9%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (20 to 50 m^2)	Large (35 to 50 m^2)	Av salary per hour (base rate)
Miners......................	68%	59%	$18.31
Helpers.....................	11%	20%	13.86
Loader operators............	7%	6%	16.53
Utility workers.............	14%	15%	16.98

The average wage for labor is $17.28 per worker-hour (including burden and average shift differential).

S) Supply Operating Cost $(Y_S) = 57.018(X)^{0.617}$
The supply cost consists of 34% explosives, 33% steel items, 15% drill bits and steel, 12% ventilation materials, 5% material waste, and 1% electricity. Supplies include drill bits and steel, powder, caps, primacord, rockbolts, water pipe, compressed air pipe, electricity, ventilation tubing, and material waste.

(E) Equipment Operating Cost $(Y_E) = 4.144(X)^{0.661}$
The equipment operating cost consists of 60% for maintenance and overhaul parts, 25% for fuel, 11% for tires, and 4% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drifting includes jumbo-mounted drifters, front-end loaders, jacklegs, auxiliary fans, and scissor lifts.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 of the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch

Rockbolt Factor For regular bolting of the entire drift, (1.2 bolts per square meter), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.12$

Supply factor $(F_S) = 1.13$

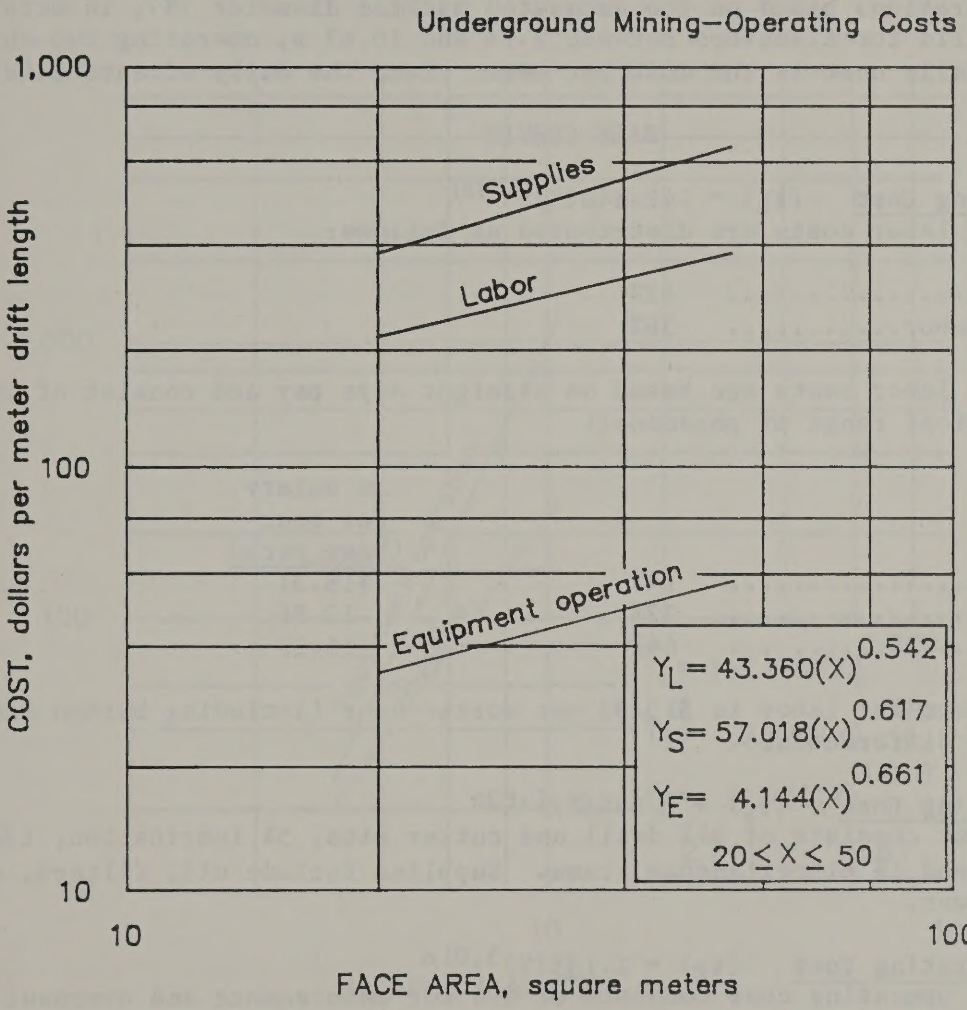
Equipment operation factor $(F_E) = 1.31$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.03$

Supply factor $(F_S) = 1.19$

Equipment operation factor $(F_E) = 1.15$



5.2.1.4.5. Drift development
LARGE DRIFTS FOR RUBBER—TIRED HAULAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.4.6. DRIFT DEVELOPMENT
DRIFT-TUNNEL BORING

This section covers costs associated with a mine using drift-tunnel boring machines (TBM's) and associated equipment.

The total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the excavated machine diameter (X), in meters. The curves are valid for diameters between 2.74 and 10.67 m, operating two shifts per day. Total daily cost is the cost per meter times the daily advance rate.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 142.640(X)^{0.000}$
The operating labor costs are distributed as follows:

Direct labor................	62%
Maintenance labor...........	38%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Operator....................	14%	$18.31
Helpers.....................	22%	13.86
Support.....................	64%	16.27

The average wage for labor is $15.92 per worker-hour (including burden and average shift differential).

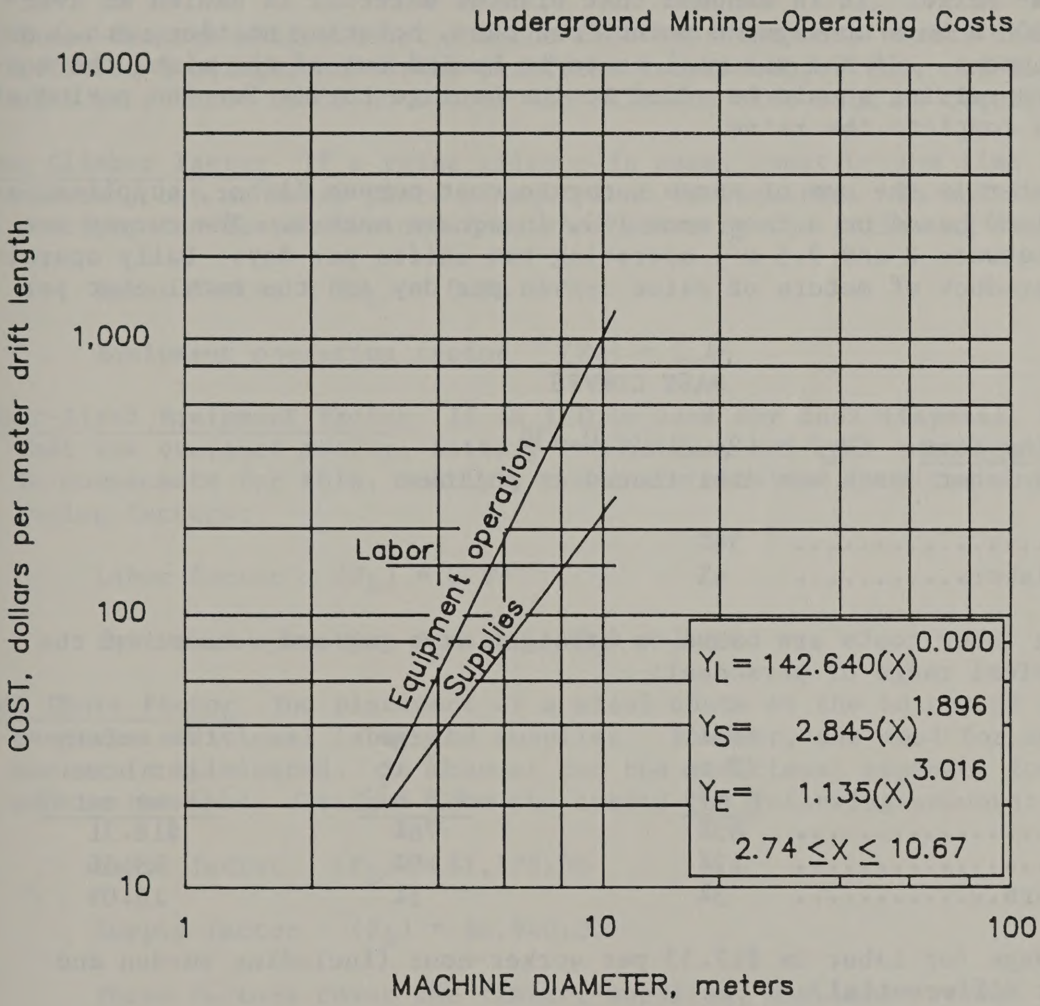
(S) Supply Operating Cost $(Y_S) = 2.845(X)^{1.896}$
The supply cost consists of 81% drill and cutter bits, 5% lubrication, 13% electricity, and 1% miscellaneous items. Supplies include oil, filters, wear items, and power.

(E) Equipment Operating Cost $(Y_E) = 1.135(X)^{3.016}$
The equipment operating cost consists of 69% for maintenance and overhaul parts and 31% for cutter costs. The equipment operating curve covers daily maintenance and repair, repair parts, and cutter costs.

ADJUSTMENT FACTOR

Contractor Factor A contractor is often used with drift-tunnel boring because of the specialized nature of the machinery. If a contractor is used, multiply the costs obtained from the curves by the following factor:

Labor factor $(F_L) = 1.94$



5.2.1.4.6. Drift development
DRIFT/TUNNEL BORING

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.5.1. RAISE DEVELOPMENT
DRIVING RAISES

The costs calculated from these curves represent two-compartment, conventionally driven raises. It is assumed that the raises are timbered and lagged, and contain water and compressed air lines. Face areas vary from 2.0 to 9.5 m^2. Advance rates range from 0.83 m per worker-shift for a 2.3-m^2 raise to 0.49 m per worker-shift for a 9.3 m^2 raise. It is assumed that blasted material is hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rail-mounted equipment. If the material is to be hauled out of the mine, the tonnage attributed to raising should be added to the haulage curves for the period of time necessary to complete the raise.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 2 and 9.5 m^2, operating two shifts per day. Daily operating cost is the product of meters of raise driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 134.819(X)^{0.438}$
The operating labor costs are distributed as follows:

Direct labor................	96%
Maintenance labor..........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (2 to 6 m^2)	Large (6 to 9.5 m^2)	Av salary per hour (base rate)
Miners......................	85%	76%	$18.31
Helpers.....................	12%	19%	13.86
Motor operators.............	3%	5%	16.09

The average wage for labor is $17.53 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 109.009(X)^{0.526}$
The supply cost consists of 51% timber, 19% explosives, 10% steel pipe, 10% ventilation materials, 4% material waste, 5% drill bits and steel, and 1% electricity. Supplies include drill bits and steel, powder, caps, lead wire, water pipe, compressed air pipe, vent duct, electricity, and timber.

(E) Equipment Operating Cost $(Y_E) = 2.267(X)^{0.757}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 33% for ground engaging components, and 10% for lubrication. The equipment

curve covers maintenance and overhaul parts, ground engaging components, and lubrication. Equipment used for raising includes stoper drills, fans, locomotives, ore cars, and overshot muckers.

ADJUSTMENT FACTORS

Timber Factor If the raise is not timbered and lagged, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.76$

Supply factor $(F_S) = 0.50$

These factors will account for the fact that the only timber needed will be for ladders, landings, and drill platforms (stull supported), and that the labor will be reduced since no timber installation time will be required.

Raise Climber Factor If a raise climber is used, construction time is significantly reduced, but an extra piece of equipment is required. To modify the costs, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.56$

Equipment operation factor $(F_E) = 1.44$

Rubber-Tired Equipment Factor If an LHD is used for muck disposal, it is assumed that the overshot mucker, battery locomotive, and rail cars would be eliminated. To compensate for this, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.99$

Equipment operation factor $(F_E) = 1.25$

Steel Chute Factor The placement of a steel chute at the bottom of a raise requires additional labor and supplies. However, the need for an overshot mucker is eliminated. To account for the additional expense, for each raise, add to the costs obtained from the curves the following amounts:

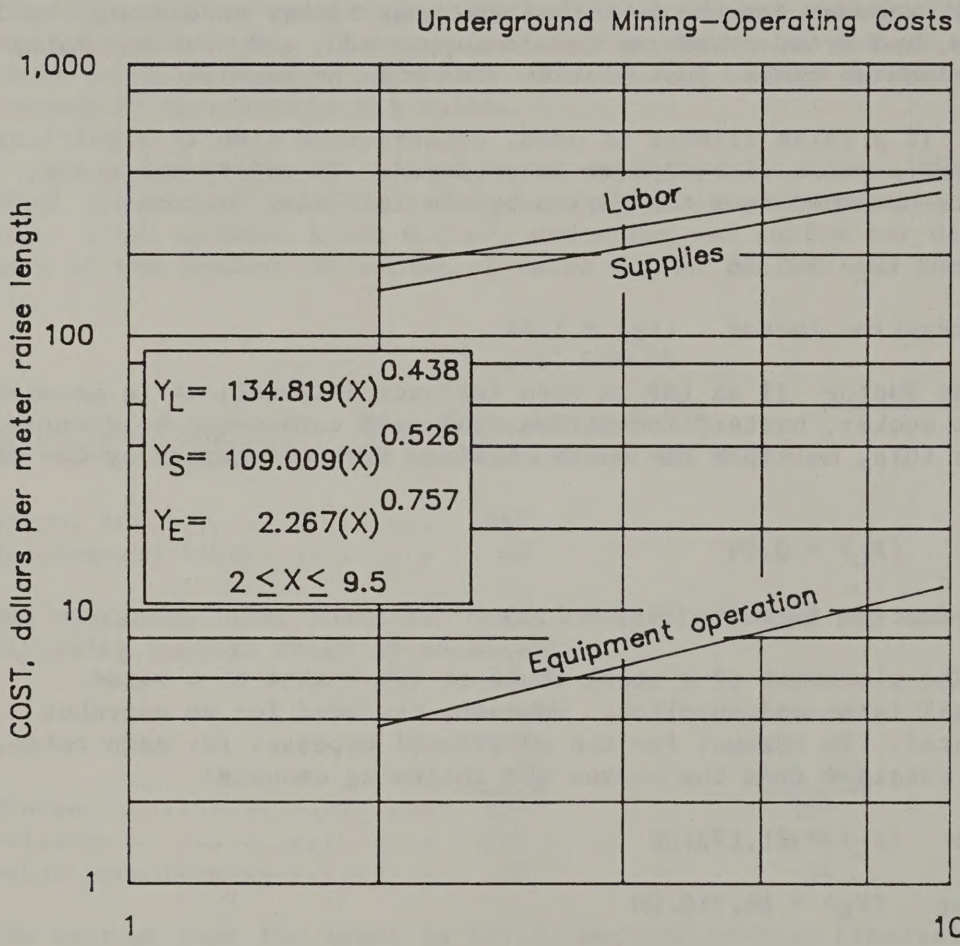
Labor factor $(F_L) = \$1,172.00$

Supply factor $(F_S) = \$6,940.00$

These factors cover the timber, supplies, and labor needed to install a steel chute with an air-piston-activated, reverse guillotine steel door.

To account for the absence of the overshot mucker multiply the equipment costs obtained from the curves by the following factor:

Equipment operation factor $(F_E) = 0.80$



5.2.1.5.1. Raise development
DRIVING RAISES

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.5.2. RAISE DEVELOPMENT
DROP RAISES

With the advent of down-the-hole drills, longhole or drop raising is becoming a popular method of driving large ventilation raises and ore passes. The costs estimated using these curves apply to any unlined raise driven using down-the-hole drills and vertical crater retreat blasting methods. Advance rates range from 1.5 m per worker-shift for a 4.6-m^2 raise to 1.0 m per worker-shift for a 13.5-m^2 raise. It is assumed that blasted material is hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rubber tired LHD's. If the material is to be hauled out of the mine, the tonnage attributed to raising should be added to the haulage curves for the period of time necessary to muck the raise.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4.5 and 13.5 m^2, operating two shifts per day. Daily operating cost is the product of meters of raise driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 58.314(X)^{0.374}$
The operating labor costs are distributed as follows:

Direct labor................	86%
Maintenance labor...........	14%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Drillers....................	29%	$18.31
Helpers.....................	15%	13.86
Blasters....................	43%	18.31
LHD operators...............	13%	16.53

The average wage for labor is $17.41 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 136.383(X)^{0.205}$
The supply cost consists of 68% blasting materials, 24% drill bits and steel, 7% miscellaneous items, and 1% timber. Supplies include drill bits and steel, blasting agent, caps, primers, detonation cord, timber, and caristrap.

(E) Equipment Operating Cost $(Y_E) = 8.895(X)^{0.711}$
The equipment operating cost consists of 43% for maintenance and overhaul parts, 41% for fuel, 9% for tires, and 7% for lubrication. The equipment curve covers daily maintenance and overhaul parts, fuel, lubrication, and tires. Equipment used in drop raising includes down-the-hole drills mounted on air tracks, portable air compressors, LHD units, and portable bit grinders.

ADJUSTMENT FACTORS

Rock Hardness Factor Down-hole-drill productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the drop raise equations by the following factors (base rock strength = 31,700 psi):

Labor $(F_L) = 0.388(C)^{0.093}$

Supplies $(F_S) = 0.579(C)^{0.054}$

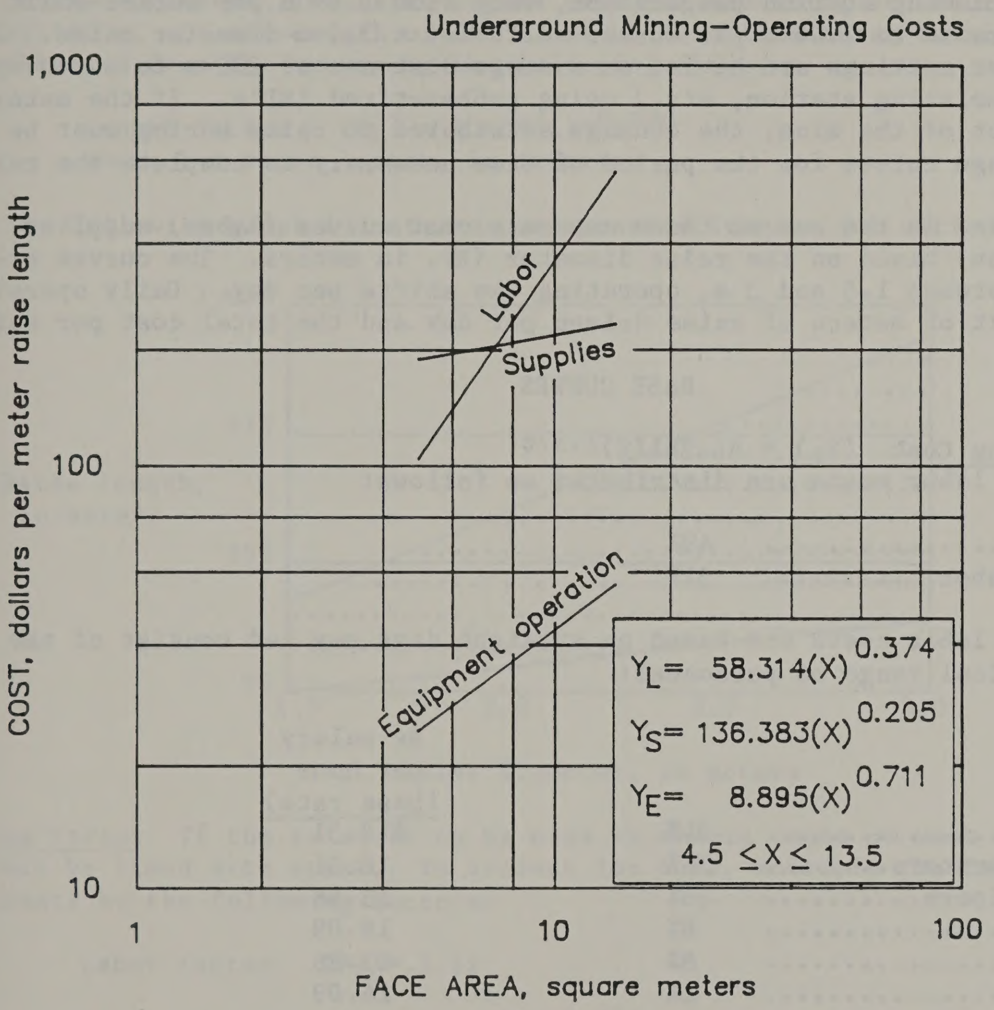
Equipment $(F_E) = 0.716(C)^{0.033}$
where: C = compressive rock strength, in pounds per square inch.

Service Installation Factor Few drop raises are used as service raises. If, however, services are installed in the raise, multiply the labor and supply costs by the following factors:

Labor $(F_L) = 1.51$

Supplies $(F_S) = 1.37$

This will account for the purchase and installation of rockbolts, ladders, landings, and pipe.



5.2.1.5.2. Raise development
DROP RAISES

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.5.3. RAISE DEVELOPMENT
RAISE BORING

The costs calculated using these curves apply to any unlined bored raise that has been drilled down and reamed up. The curves take into account costs incurred in preparation of upper and lower stations, drill platform construction, boring machine installation, pilot hole drilling, reaming operations, and muck removal. Average advance rates, including station preparation, vary from 1.89 m per worker-shift for a 1.5-m-diameter raise to 1.06 m per worker-shift for a 3.0-m-diameter raise. It is assumed that reamer cuttings are hauled an average distance of 200 m to a conveyance point (ore pass, hoisting station, etc.) using rubber-tired LHD's. If the material is to be hauled out of the mine, the tonnage attributed to raise boring must be added to the haulage curves for the period of time necessary to complete the raise.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the raise diameter (X), in meters. The curves are valid for areas between 1.5 and 3 m, operating two shifts per day. Daily operating cost is the product of meters of raise driven per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 81.941(X)^{1.376}$
The operating labor costs are distributed as follows:

Direct labor................	49%
Maintenance labor...........	51%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	31%	$18.31
Raise bore operators........	26%	18.31
Raise bore helpers..........	26%	13.86
LHD operators...............	8%	16.09
Helpers.....................	8%	13.86
Nippers.....................	1%	16.09

The average wage for labor is $16.60 per worker-hour (including burden and average shift differential).

(S) Supply Operation Cost $(Y_S) = 180.595(X)^{1.097}$
The supply cost consists of 83% drill and cutter bits, 5% material waste, 4% drill steel, 3% electricity, 3% blasting materials, 1% rock support, and 1% miscellaneous items. Supplies include drill bits and steel for the air legs, drill bits, cutter bits, and drill steel for the boring machine, blasting agent, caps, detonation cord, rock bolts, wire mesh, concrete, and electricity.

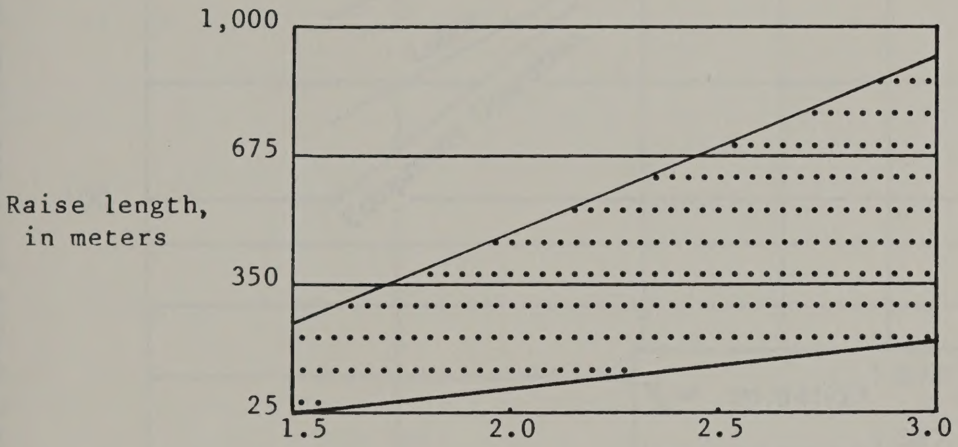
(E) Equipment Operating Cost $(Y_E) = 46.568(X)^{1.759}$
The equipment operating cost consists of 69% for maintenance and overhaul parts, 22% for ground engaging components, 7% for lubrication, and 2% for fuel and tires. The equipment curve covers overhaul and maintenance parts, ground engaging components, fuel, lubrication, and tires. The equipment used for raise boring and station preparation includes air leg drills, LHD units, and raise bore machines.

ADJUSTMENT FACTORS

Raise Length Factor Because of the high costs incurred in station preparation and machine setup, the actual cost per meter will decrease as the length of the raise increases. The raise curves were derived using an assumed raise length of 100 m. If the length of the raise differs from this, multiply the costs obtained from the curves by the following factor:

Length factor $(F_L) = 1.468(L)^{-0.080}$
where L = raise length, in meters.

The following graph illustrates recommended lengths for various raise diameters:



Raise diameter, in meters

Lining Factor If the raise is to be used as an ore chute or vent raise, it may be lined with steel. To account for this, multiply the labor and supply costs by the following factors:

Labor factor $(F_L) = 1.12$

Supply factor $(F_S) = 1.27(X)^{0.276}$
where X = raise diameter, in meters.

Service Installation Factor If services are installed in the raise, multiply the labor and supply costs by the following factors:

Labor factor $(F_L) = 1.21$

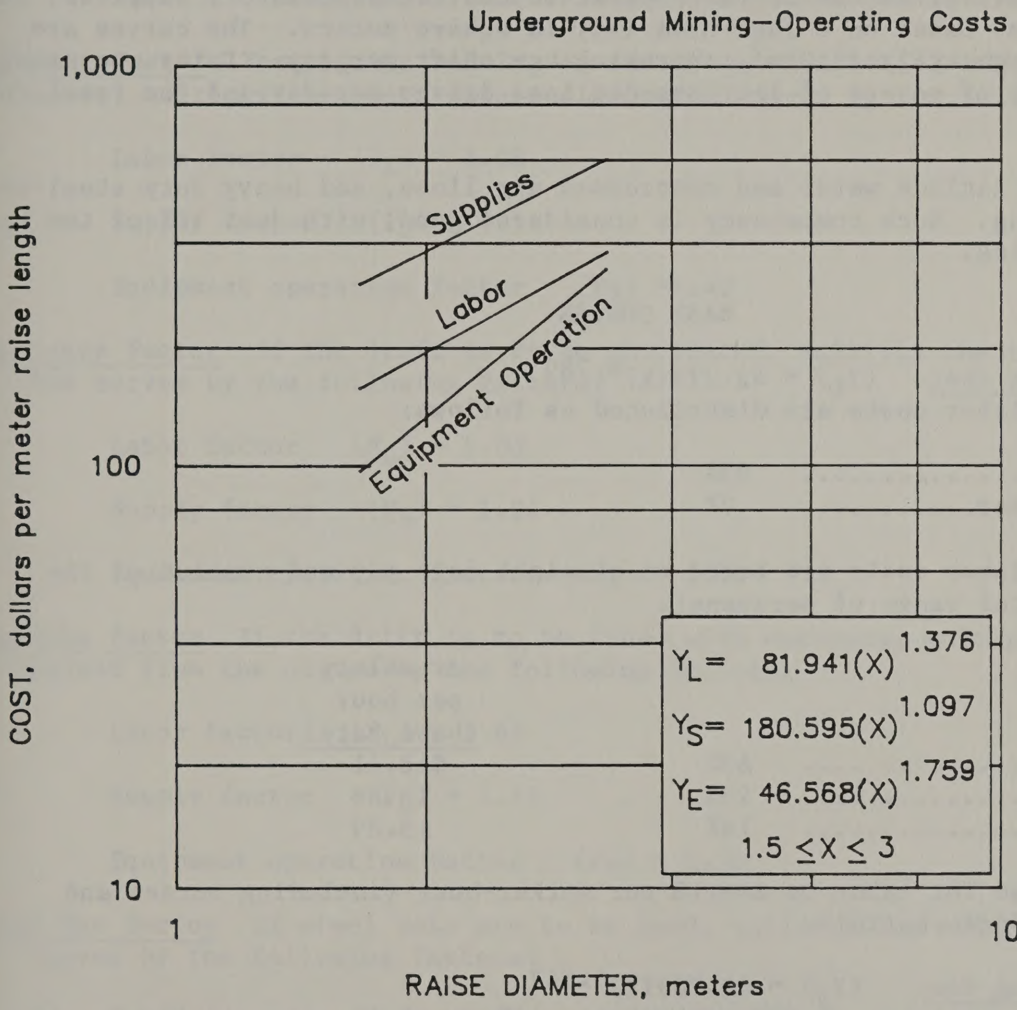
Supply factor $(F_S) = 1.16$

This will account for the purchase and installation of rockbolts, ladders, landings, and pipe.

Rock Hardness Factor The hardness of the rock being bored has a great effect on both penetration rate and cutter life. The curves were derived using rock with an assumed compressive strength of 50,000 psi. Total cost may range from 25% of the cost for rock with a compressive strength of 14,500 psi to 200% of the cost for rock with a compressive strength of 75,000 psi. Actual variances are very difficult to estimate; however, as a general rule of thumb, the total cost per meter obtained from the curves may be multiplied by the following factor to compensate for differences in rock hardness:

Hardness factor $(F_H) = 0.0000018(C)^{1.231}$

where C = compressive strength of rock, in pounds per square inch. See table A-1 in the appendix for average compressive rock strengths.



5.2.1.5.3. Raise development
RAISE BORING

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.6. INCLINES-DECLINES

The inclines-declines curve is based on using jumbo drills and LHD haulage and assumes the opening is at a 10° angle. The cost per meter of advance does not change for angles 5° to 15 °. The average advance is 2.2 m/d in smaller openings and 0.6 m/d overall in larger openings.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 4 and 50 m^2, operating one shift per day. Daily operating cost is the product of meters of inclines-declines driven per day and the total cost per meter.

Services installed include water and compressed air lines, and heavy duty steel-reinforced vent tubing. Rock competency is considered good, with just 10% of the back requiring rockbolting.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 42.779(X)^{0.789}$
The operating labor costs are distributed as follows:

Direct labor................	93%
Maintenance labor..........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	63%	$18.11
Helpers.....................	23%	13.66
LHD operator................	14%	15.89

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 48.709(X)^{0.567}$
The supply cost consists of 40% explosives, 44% steel items, and 16% miscellaneous items. Supplies include drill bits and steel, powder, caps, primer, rockbolts, vent line, compressed air pipe, and water pipe.

(E) Equipment Operating Cost $(Y_E) = 1.498(X)^{1.303}$
The equipment operating cost consists of 49% for repair parts, 32% for fuel and lubrication, and 19% for tires. The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for drills, fans, LHD's, and other equipment used to drive the opening.

ADJUSTMENT FACTORS

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the curves by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Rockbolt Factor For regular bolting of the entire drift (1.2 bolts per square meter) multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.08$

Supply factor $(F_S) = 1.14$

Equipment operation factor $(F_E) = 1.42$

Shotcrete Factor If the drift is to be shotcreted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.03$

Supply factor $(F_S) = 1.24$

Equipment operation factor $(F_E) = 1.15$

Concrete Factor If the drift is to be lined with concrete, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.64$

Supply factor $(F_S) = 1.72$

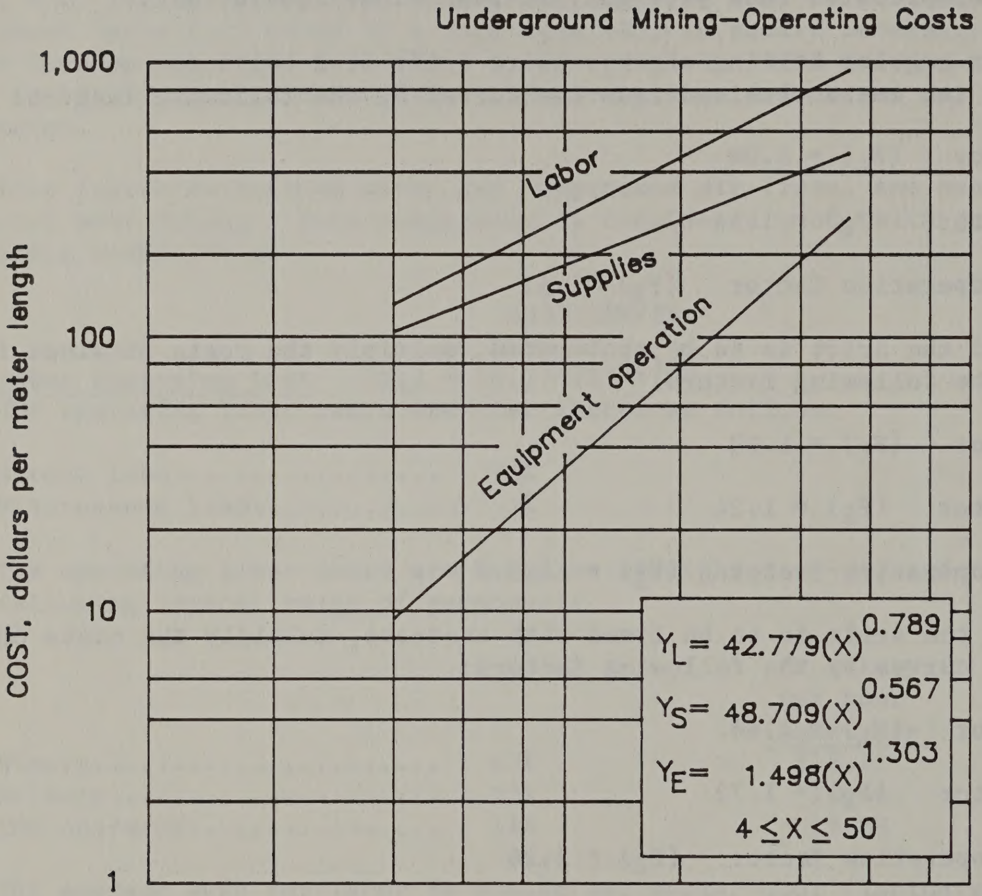
Equipment operation factor $(F_E) = 2.26$

Steel Set Factor If steel sets are to be used, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.37$

Supply factor $(F_S) = 2.47$

Equipment operation factor $(F_E) = 1.19$



5.2.1.6. Inclines/Declines

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.7. LARGE UNDERGROUND EXCAVATIONS

The costs derived from these curves apply to a horizontal opening driven with a two boom jumbo and LHD haulage a distance of 200 m. It is assumed the walls will be supported with rockbolts and wire mesh. If the material is to be hauled out of the mine, the tonnage attributed to excavating should be added to to the haulage curves for the period of time necessary to complete the excavation. It is assumed that all equipment needed for the excavation will be required for the mining operation, and will be considered in the mine equipment cost curve.

Total cost per meter is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a face area (X), in square meters. The curves are valid for areas between 13.94 and 334.45 m^2, operating one shift per day. Daily operating cost is the product of meters of excavations per day and the total cost per meter.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 10.817(X)^{0.947}$
The operating labor costs are distributed as follows:

Direct labor...............	91%
Maintenance labor..........	9%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners.....................	76%	$18.11
Helpers....................	19%	13.66
Motor operators............	5%	15.89

The average wage for labor is $17.16 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 23.050(X)^{0.793}$
The supply cost consists of 66% explosives, 28% steel items, and 6% ventilation. Supplies include drill bits and steel, powder, caps, primer cord, water pipe, compressed air pipe, vent duct, rockbolts and wire mesh.

(E) Equipment Operating Cost $(Y_E) = 1.739(X)^{0.917}$
The equipment operating cost consists of 45% for overhaul and repair parts, 35% for tires, and 20% for fuel and lubrication. The equipment operating curve covers daily maintenance and overhaul parts and lubrication for drills, fans, LHD's, and roof bolters.

ADJUSTMENT FACTORS

Track Haulage Factor If track haulage is used, the LHD will be replaced by a battery locomotive, overshot mucker, and rail cars. Rubber-tired equipment is more expensive to operate than rail-mounted equipment. Therefore, to account for cost of the equipment and installing rail, multiply the costs obtained from the curves by the following factors:

Supply factor $(F_S) = 1.13$

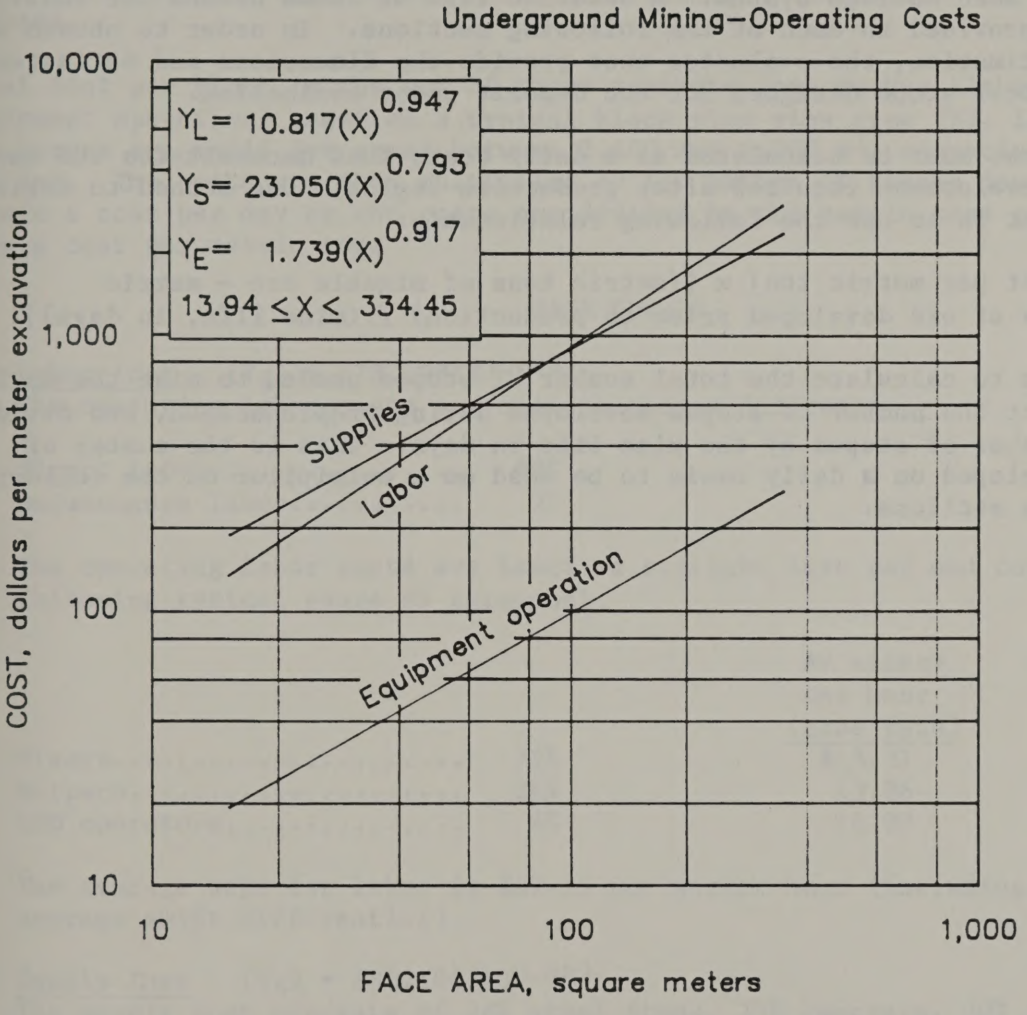
Equipment operation factor $(F_E) = 0.71$

Shotcrete Factor For additional expenses associated with coating the excavation to a shotcrete depth of 3.8 cm, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.05$

Supply factor $(F_S) = 1.59$

Equipment operation factor $(F_E) = 1.09$



5.2.1.7. Large underground excavations

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9. STOPE PREPARATION

Stope preparation includes any operation and excavation necessary to bring a stope into full-scale production. Stope preparation is, of course, different for every mining method, so each method is dealt with individually in the following sections. In general, however, costs derived from the following curves cover every operation and excavation needed to develop the stope for full capacity extraction, and to connect it with the main haulage system. A detailed list of items needed for individual methods is provided in each of the following sections. In order to obtain an accurate cost estimation, the evaluator must provide the dimensions and estimated tonnage of a typical stope designed for the deposit under evaluation.

Each operating cost must be calculated as a daily cost, that necessitates the amount of daily stope development required after production begins. One method to arrive at this daily cost is to use the following relationship:

daily cost = [cost per metric ton] x [(metric tons of minable ore - metric tons of ore developed prior to production) / (mine life, in days)].

Another method is to calculate the total number of stopes needed to mine the entire ore body, subtract the number of stopes developed during preproduction, and divide the remaining number of stopes by the mine life in days. This is the number of stopes to be developed on a daily basis to be used as a multiplier on the following stope preparation sections.

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.1. STOPE PREPARATION BLOCK CAVING

Items needed for preparation of a block caving stope include panel drifts, access drifts, grizzly drifts, undercut drifts, draw raises, transfer raises, and cave induction. All ore chutes, grizzlies, and support and reinforcement items are included in the curve. The curves cover blocks in horizontal area and of any height. Costs represent a system in which ore is moved to the main haulage level by gravity methods.

Total cost per block is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a typical block plan view area (X), in square meters. The curves are valid for areas between 2,400 and 6,300 m^2, operating two shifts per day. The costs are then multiplied by the number of blocks developed per day to obtain a cost per day or the costs are divided by the metric tons per block to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 573.198(X)^{0.881}$
The operating labor costs are distributed as follows:

Direct labor................	98%
Maintenance labor...........	2%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	72%	$18.31
Helpers.....................	24%	13.86
LHD operators...............	4%	16.09

The average wage for labor is $17.15 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 650.100(X)^{0.883}$
The supply cost consists of 26% steel items, 25% concrete, 20% timber, 18% blasting supplies, 5% contingency, 4% drill bits and steel, and 2% all other items. Supplies necessary for the development of a block caving stope include drill bits and steel, blasting agent, caps, timber, concrete, rail, water and compressed air pipe, ventilation ducting, rockbolts, electricity, and steel for ore chutes and grizzlies.

(E) Equipment Cost $(Y_E) = 11.355(X)^{0.885}$
The equipment operating cost consists of 76% for maintenance and overhaul parts, 9% for tires, 8% for fuel, and 7% for lubrication. The equipment curve covers

daily maintenance and overhaul parts, tires, fuel, and lubrication. Equipment used in stope preparation for block caving includes jacklegs, auxiliary fans, overshot muckers, locomotives, ore cars, LHD's, and fan drills.

ADJUSTMENT FACTORS

Nongravity Caving Factor If the ore is to be transferred to the main haulage system using slushers or LHD's, adjustments must be made to the costs. Multiply the costs obtained from the curves by the following factors:

Slushers:

Labor factor $(F_L) = 0.85$

Supply factor $(F_S) = 0.83$

Equipment operation factor $(F_E) = 0.99$

LHD's:

Labor factor $(F_L) = 0.60$

Supply factor $(F_S) = 0.84$

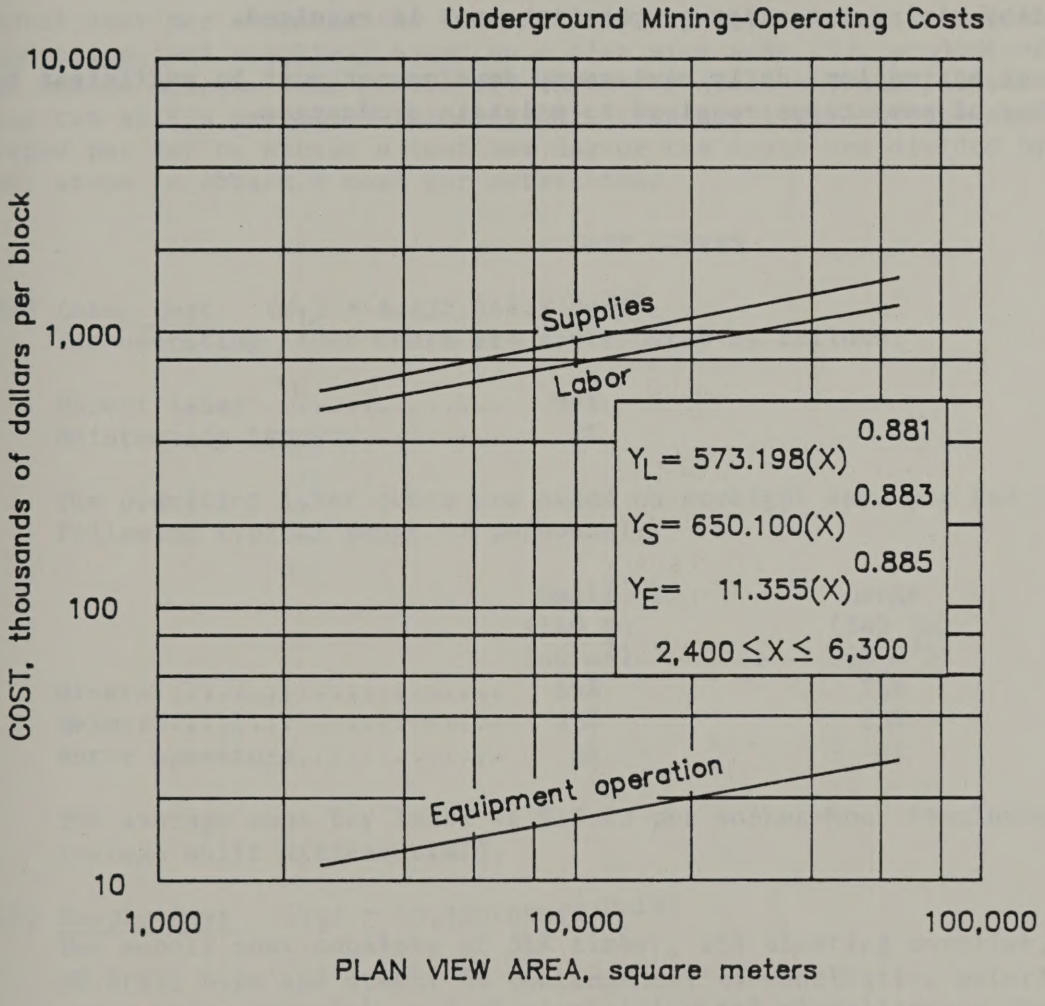
Equipment operation factor $(F_E) = 0.77$

Rock Hardness Factor Block caving development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.1. Stope preparation
BLOCK CAVING

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.2. STOPE PREPARATION CONTINUOUS MINING

Continuous miner stopes are initiated with multientry panels directly off the main haulage level. The method changes little from the initial cuts to the completion of the stope. The cost of the main haulage level cannot be included in the stope preparation costs since many stopes benefit from this one entry. Because the cost per ton of excavating the production entries from the haulage level is the same as that for production mining, no stope preparation cost is required.

For operating cost estimation, daily haulageway development must be sufficient to open up the number of new stopes required to maintain production.

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.3. STOPE PREPARATION CUT AND FILL

Items needed for preparation of a cut-and-fill stope include a crosscut from the main haulageway, a blind raise access cut with two ore chutes, a manway, a timber slide, and an initial bottom sill cut. The curves cover stopes ranging from 2.4 m wide by 61.0 m long to 4.9 m wide by 106.7 m long and of any reasonable height.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 140 and 540 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 4{,}422.948(X)^{0.369}$
The operating labor costs are distributed as follows:

Direct labor................	97%
Maintenance labor...........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (140 to 340 m^2)	Large (340 to 540 m^2)	Av salary per hour (base rate)
Miners......................	69%	73%	$18.31
Helpers.....................	25%	23%	13.86
Motor operators.............	6%	4%	16.09

The average wage for labor is $17.13 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 16{,}203.090(X)^{0.197}$
The supply cost consists of 31% timber, 25% blasting supplies, 24% steel items, 5% drill bits and steel, 5% contingency, 4% ventilation material, 3% sandfill preparation material, and 3% electricity and miscellaneous items. Supplies necessary for the development of a cut-and-fill stope include drill bits and steel, blasting agent, caps, timber, rail, ballast, steel pipe, ventilation ducting, rockbolts, burlap, electricity, and steel for ore chutes.

(E) Equipment Cost $(Y_E) = 311.270(X)^{0.201}$
The equipment operating cost consists of 85% for maintenance and overhaul parts, 8% for lubrication, and 7% for ground engaging components. The equipment curve covers maintenance and overhaul parts, ground engaging components, and lubrication. Equipment used in stope preparation for cut-and-fill mining includes

jacklegs, stopers, jackhammers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

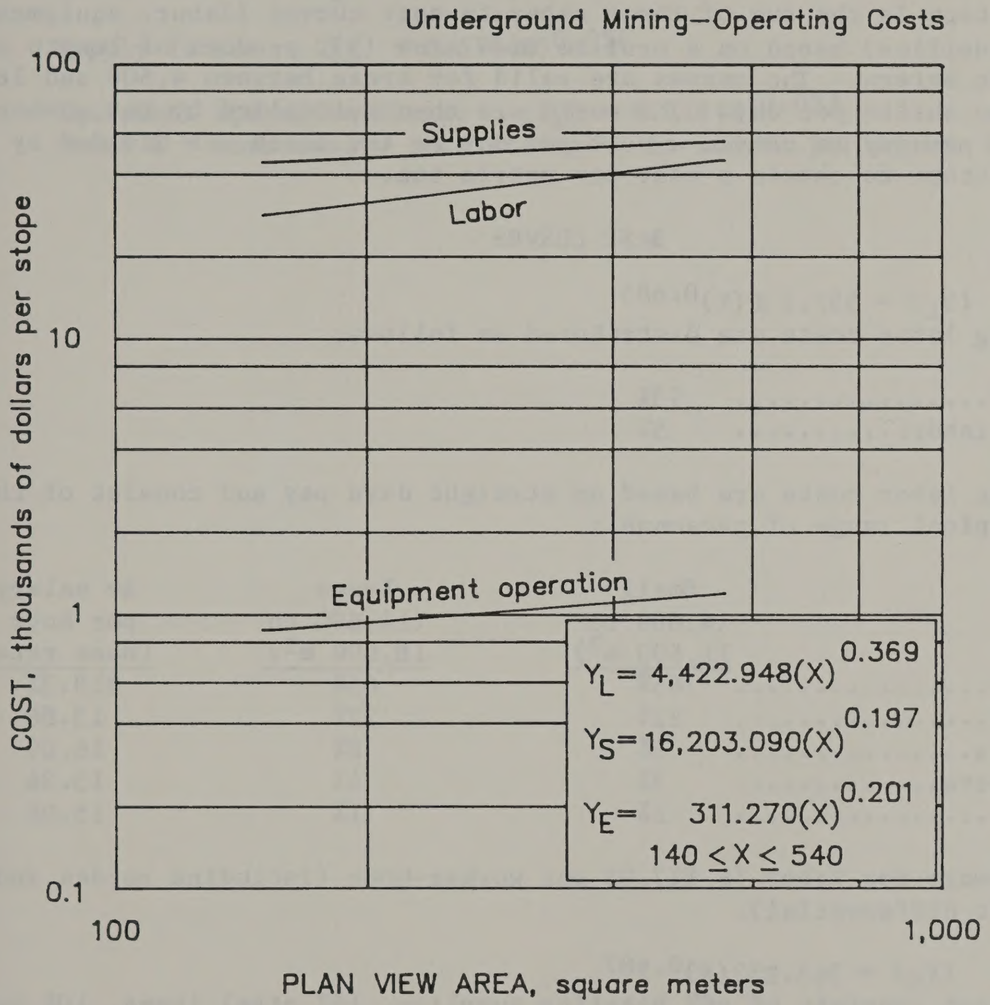
ADJUSTMENT FACTOR

Rock Hardness Factor Cut-and-fill stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the cut-and-fill stope preparation equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.3. Stope preparation
CUT AND FILL

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.4. STOPE PREPARATION LONGHOLE-SUBLEVEL

Items needed for preparation of a sublevel-longhole stope include sublevels, a bottom sill cut, a scram drift, crosscuts connecting the bottom sill and scram drifts, an access raise, and a slot raise. The curves cover stopes ranging from 5.4 m wide by 61.0 m high by 76.2 m long to 18.3 m wide X 121.9 meters high by 152.4 m long.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a profile view area (X), product of length and height, in square meters. The curves are valid for areas between 4,600 and 18,600 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 357.256(X)^{0.685}$
The operating labor costs are distributed as follows:

Direct labor................	95%
Maintenance labor...........	5%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (4,600 to 11,600 m^2)	Large (11,600 to 18,600 m^2)	Av salary per hour (base rate)
Miners......................	65%	65%	$18.31
Helpers.....................	22%	22%	13.86
LHD operators...............	9%	8%	16.09
Utility workers.............	3%	4%	15.94
Surveyors...................	1%	1%	15.08

The average wage for labor is $17.05 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 363.252(X)^{0.687}$
The supply cost consists of 46% blasting supplies, 16% steel items, 10% drill bits and steel, 9% ventilation materials, 9% timber, 5% contingency, and 5% electricity and miscellaneous items. Supplies necessary for the development of a sublevel-longhole stope include drill bits and steel, blasting agent, caps, timber, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Cost $(Y_E) = 23.555(X)^{0.707}$
The equipment operating cost consists of 57% for maintenance and overhaul parts, 19% for tires, 17% for fuel, and 7% for lubrication. The equipment curve covers

maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for sublevel-longhole mining includes jacklegs, auxiliary fans, LHD's, booster compressors, jumbo-mounted drifters, and air-track-mounted longhole drills.

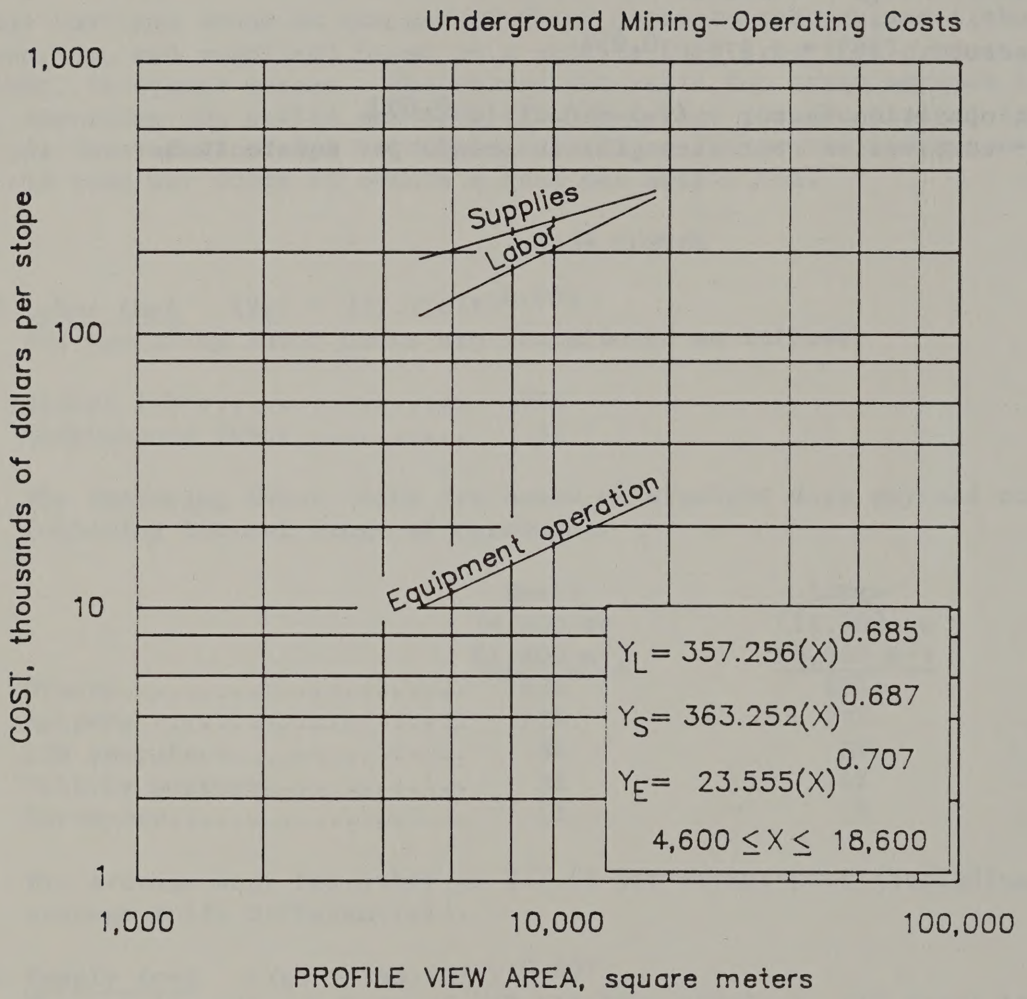
ADJUSTMENT FACTOR

Rock Hardness Factor Sublevel-longhole stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.392(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.4. Stope preparation
LONGHOLE/SUBLEVEL

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.5. STOPE PREPARATION
RESUING

Items needed for preparation of a resuing stope include an access drift along the stope in the footwall, a blind raise access cut with two ore chutes and a manway, and a starter drift running the length of the stope. The blind raise runs the entire height of the stope, and both the raise and the starter drift are driven in ore and waste. Ore excavated during development is generally discarded as waste. The curves cover stopes ranging from 22.9 m long by 18.3 m high to 45.7 m long by 38.1 m high, and 1.5 m in width.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a profile view area (X), product of length and height, in square meters. The curves are valid for areas between 350 and 2,000 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 1{,}077.505(X)^{0.448}$
The operating labor costs are distributed as follows:

Direct labor................	97%
Maintenance labor...........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	86%	$18.31
Helpers.....................	9%	13.86
Motor operators.............	5%	18.31

The average wage for labor is $17.80 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 4{,}004.706(X)^{0.290}$
The supply cost consists of 61% steel items, 13% blasting supplies, 12% timber, 6% ventilation materials, 4% drill bits and steel, 3% contingency, and 1% electricity and miscellaneous items. Supplies necessary for the development of a resuing stope include drill bits and steel, blasting agent, caps, timber, rail, ballast, steel pipe, ventilation ducting, electricity, and steel for ore chutes.

(E) Equipment Cost $(Y_E) = 24.097(X)^{0.499}$
The equipment operating cost consists of 67% for maintenance and overhaul parts, 16% for ground engaging components, 9% for fuel, and 8% for lubrication. The

equipment curve covers maintenance and overhaul parts, ground engaging components, fuel, and lubrication. Equipment used in stope preparation for resuing includes jacklegs, stopers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

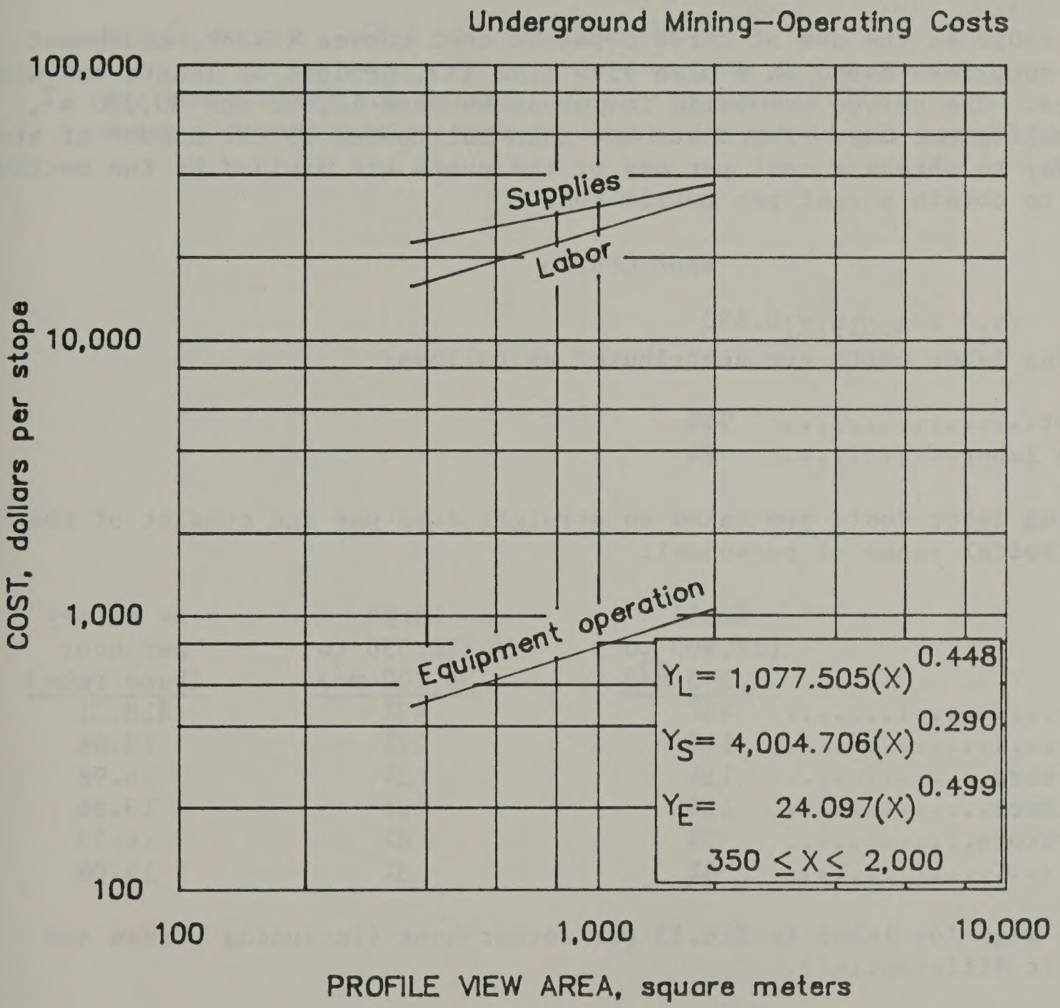
ADJUSTMENT FACTOR

Rock Hardness Factor Resuing stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = the compressive rock strength, in pounds per square inch.



5.2.1.9.5. Stope preparation
RESUING

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.6. STOPE PREPARATION ROOM AND PILLAR, MEDIUM TO HARD ROCK

The main item needed to prepare a metallic room-and-pillar stope is an access drift from a main haulageway running the entire length of the panel. The curves cover panels ranging from 12,900 to 30,200 m^2 in horizontal area, and of any feasible height.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width in square meters. The curves are valid for areas between 12,900 and 30,200 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per panel to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 4.019(X)^{0.890}$
The operating labor costs are distributed as follows:

Direct labor................	92%
Maintenance labor...........	8%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (12,900 to 21,550 m^2)	Large (21,550 to 30,200 m^2)	Av salary per hour (base rate)
Miners......................	46%	43%	$18.31
Helpers.....................	11%	22%	13.86
Utility workers.............	15%	12%	16.98
Utility helpers.............	15%	12%	13.86
Loader operators............	7%	8%	16.53
Surveyors...................	6%	3%	15.08

The average wage for labor is $16.53 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 2.686(X)^{0.997}$
The supply cost consists of 58% blasting supplies, 12% steel items, 11% drill bits and steel, 10% ventilation materials, 5% contingency, and 4% electricity and miscellaneous items. Supplies necessary for the development of a metallic room-and-pillar stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation materials, electricity, and rockbolts.

(E) Equipment Cost $(Y_E) = 0.046(X)^{1.128}$
The equipment operating cost consists of 59% for maintenance and overhaul parts, 21% for fuel, 13% for tires, and 7% for lubrication. The equipment curve covers

maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for metallic room-and-pillar mining includes auxiliary fans, front-end loaders, jacklegs, scissor lifts, and jumbo-mounted drifters.

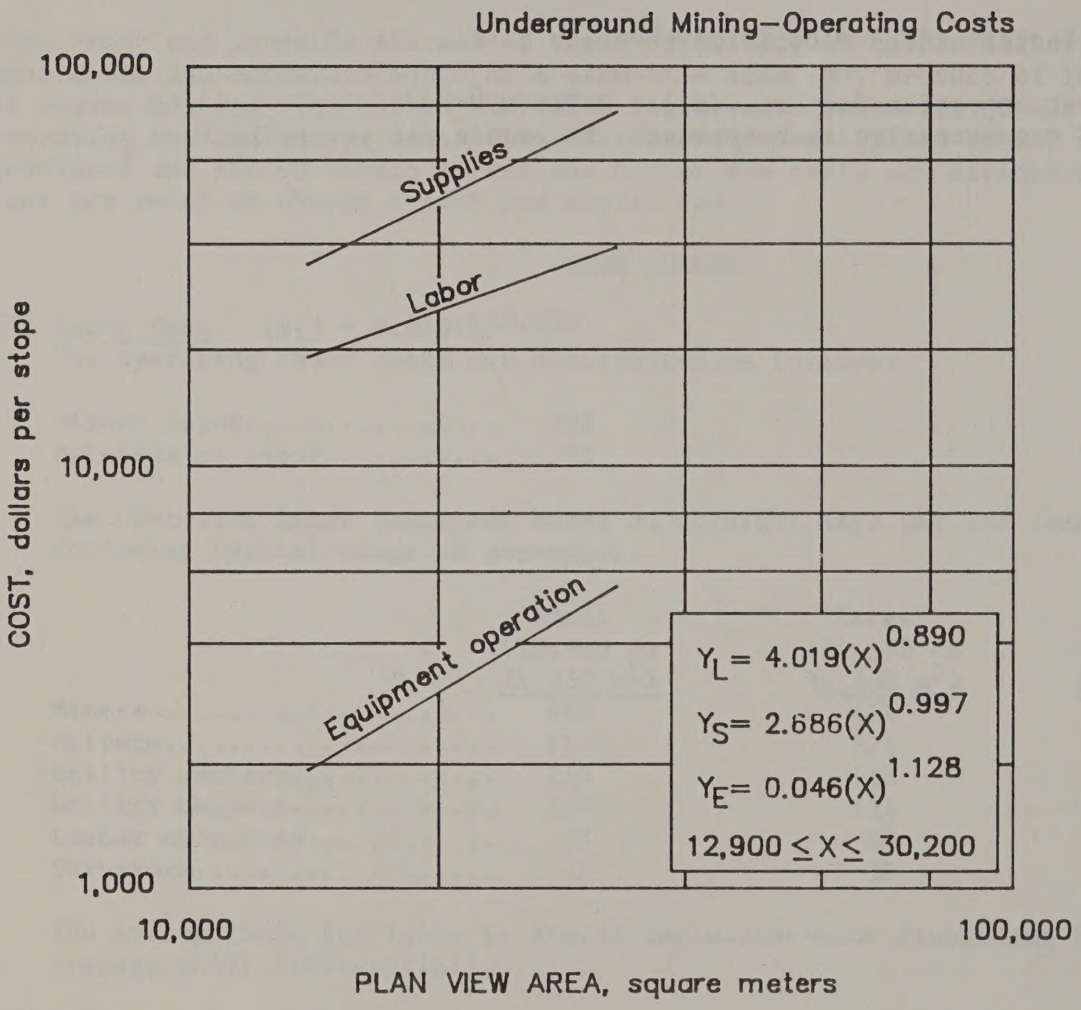
ADJUSTMENT FACTOR

Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.6. Stope preparation
ROOM & PILLAR, MEDIUM TO HARD ROCK

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.7. STOPE PREPARATION
ROOM AND PILLAR, NONMETALLIC SOFT ROCK

The main item needed to develop a nonmetallic room-and-pillar stope consists of an access drift from a main haulageway running the entire length of the panel. The curves cover panels ranging from 14,800 to 33,500 m^2 in horizontal area, and of any feasible height.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 14,800 and 33,500 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per panel to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 43.903(X)^{0.557}$
The operating labor costs are distributed as follows:

Direct labor................	93%
Maintenance labor...........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (14,800 to 24,150 m^2)	Large (24,150 to 33,500 m^2)	Av salary per hour (base rate)
Miners......................	15%	23%	$18.31
Loader operators............	10%	15%	16.53
Shuttle operators...........	10%	15%	16.09
Utility workers.............	29%	23%	16.98
Utility helpers.............	24%	16%	13.86
Surveyors...................	12%	8%	15.08

The average wage for labor is $16.30 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 20.909(X)^{0.632}$
The supply cost consists of 63% steel items, 10% drill bits and steel, 10% blasting supplies, 5% electricity, 4% ventilation materials, 4% contingency, and 4% miscellaneous items. Supplies necessary for the development of a nonmetallic room-and-pillar stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation materials, electricity, and rockbolts.

(E) Equipment Cost $(Y_E) = 0.117(X)^{0.908}$
The equipment operating cost consists of 69% for maintenance and overhaul parts, 17% for tires, 11% for lubrication, and 3% for fuel. The equipment curve covers

maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for nonmetallic room-and-pillar mining includes roof bolters, ANFO trucks, undercutters, loaders, shuttle cars, portable transformers-rectifiers, and jumbo-mounted drifters.

ADJUSTMENT FACTOR

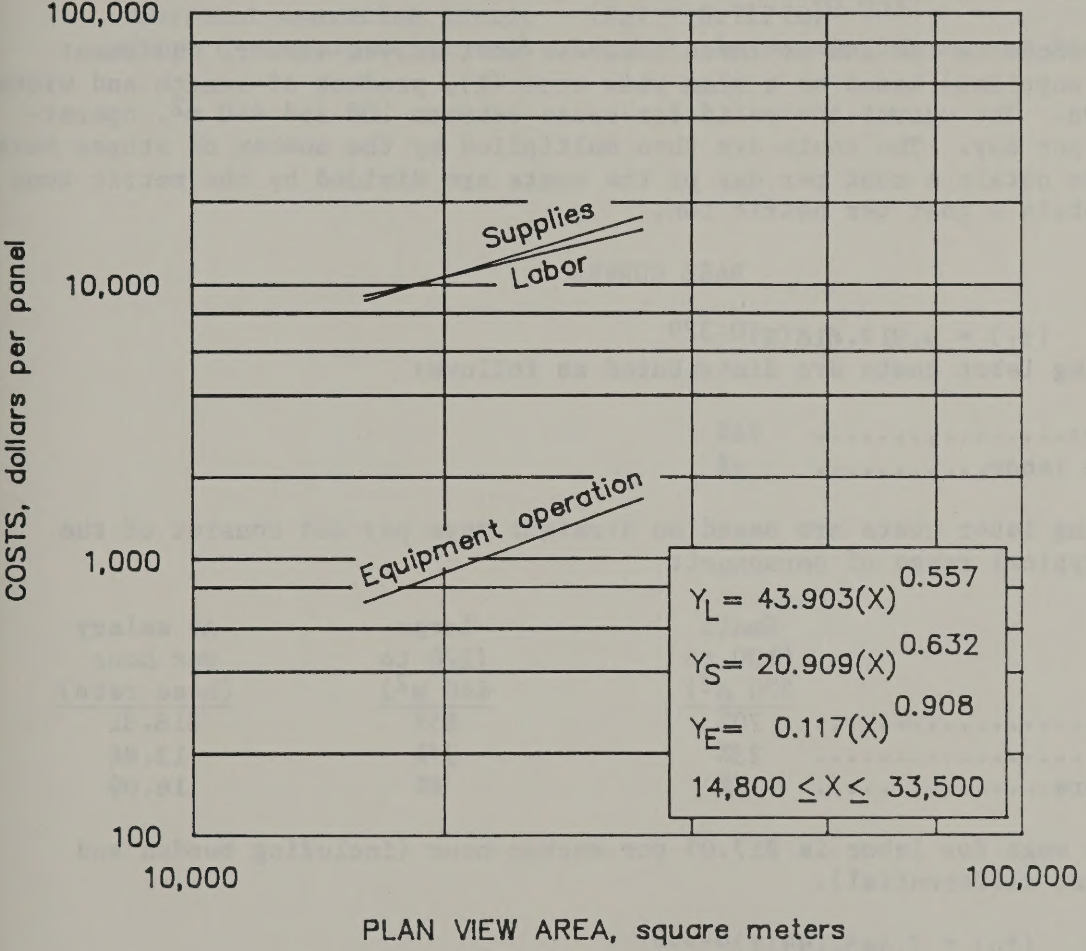
Rock Hardness Factor Drifting productivity is directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Underground Mining—Operating Costs



5.2.1.9.7. Stope preparation
ROOM & PILLAR, NONMETALLIC SOFT ROCK

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.8. STOPE PREPARATION
SHRINKAGE

Items needed for preparation of a shrinkage stope include a bottom sill cut, a scram drift, crosscuts from the scram to the bottom sill drift, an access raise, and dog_ holes along the raise to connect with the stope as mining progresses. The curves are based on the assumption that ore will be drawn from the crosscuts using LHD's. Stopes ranging from 2.4 m wide by 45.7 m long to 5.5 m wide by 76.2 m long are covered by the curve. Stope height is fixed at 61 m.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 100 and 440 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 9,917.618(X)^{0.329}$
The operating labor costs are distributed as follows:

Direct labor................	96%
Maintenance labor...........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 270 m^2)	Large (270 to 440 m^2)	Av salary per hour (base rate)
Miners......................	70%	65%	$18.31
Helpers.....................	23%	27%	13.86
LHD operators...............	7%	8%	16.09

The average wage for labor is $17.09 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 7,445.199(X)^{0.335}$
The supply cost consists of 37% blasting supplies, 19% steel items, 15% timber, 11% ventilation materials, 9% drill bits and steel, 5% contingency, and 4% electricity and miscellaneous items. Supplies necessary for the development of a shrinkage stope include drill bits and steel, blasting agent, caps, timber, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Cost $(Y_E) = 373.610(X)^{0.388}$
The equipment operating cost consists of 64% for maintenance and overhaul parts, 20% for tires, 10% for fuel, and 6% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in

stope preparation for shrinkage mining includes stopers, jacklegs, auxiliary fans, LHD's, and jumbo-mounted drifters.

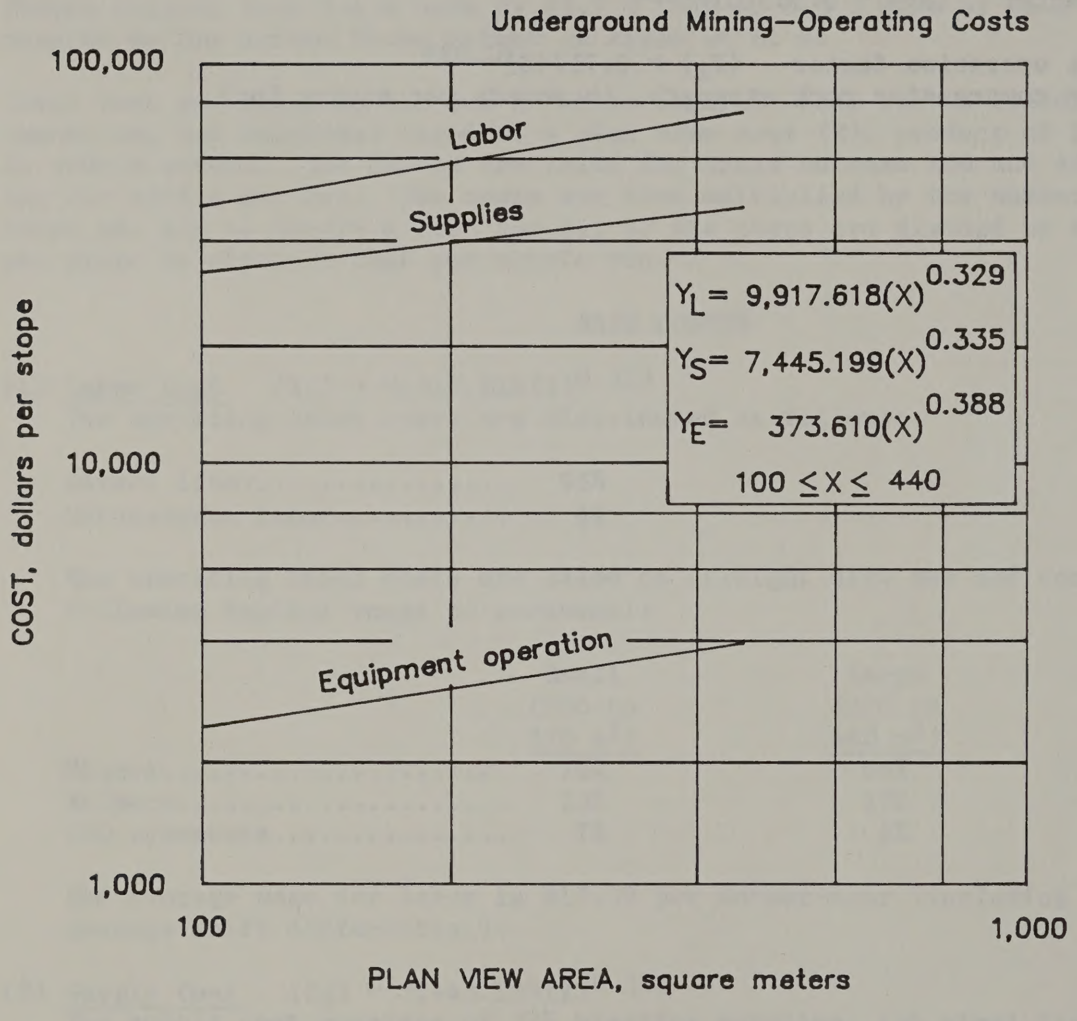
ADJUSTMENT FACTOR

Rock Hardness Factor Shrinkage stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 of the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.399(C)^{0.091}$

Supply factor $(F_S) = 0.585(C)^{0.053}$

Equipment operation factor $(F_E) = 0.717(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.8. Stope preparation
SHRINKAGE

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.9. STOPE PREPARATION SQUARE SET

Items needed for preparation of a square set stope include a crosscut from the main haulageway, an initial bottom sill cut, and a blind raise access cut with two ore chutes, a manway, and a timber slide. The curves cover stopes ranging from 2.4 m wide by 45.7 meters long to 4.9 m wide by 76.2 m long, and of any reasonable height.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 100 and 400 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 6{,}114.261(X)^{0.340}$
The operating labor costs are distributed as follows:

Direct labor................	97%
Maintenance labor...........	3%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 250 m^2)	Large (250 to 400 m^2)	Av salary per hour (base rate)
Miners......................	69%	73%	$18.31
Helpers.....................	26%	24%	13.86
Motor operators.............	5%	3%	16.09

The average wage for labor is $16.93 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 17{,}393.433(X)^{0.208}$
The supply cost consists of 43% timber, 20% steel items, 19% blasting supplies, 9% contingency, 3% drill bits and steel, 3% ventilation materials, and 3% electricity and miscellaneous items. Supplies necessary for the development of a square set stope include drill bits and steel, blasting agent, caps, timber, blocking, rail, ballast, steel pipe, ventilation ducting, electricity, and steel for ore chutes.

(E) Equipment Cost $(Y_E) = 375.160(X)^{0.178}$
The equipment operating cost consists of 83% for maintenance and overhaul parts, 10% for lubrication, and 7% for ground engaging components. The equipment curve covers maintenance and overhaul parts, ground engaging components, and lubrication. Equipment used in stope preparation for square set mining includes jack-

legs, stopers, auxiliary fans, overshot muckers, locomotives, ore cars, and slushers.

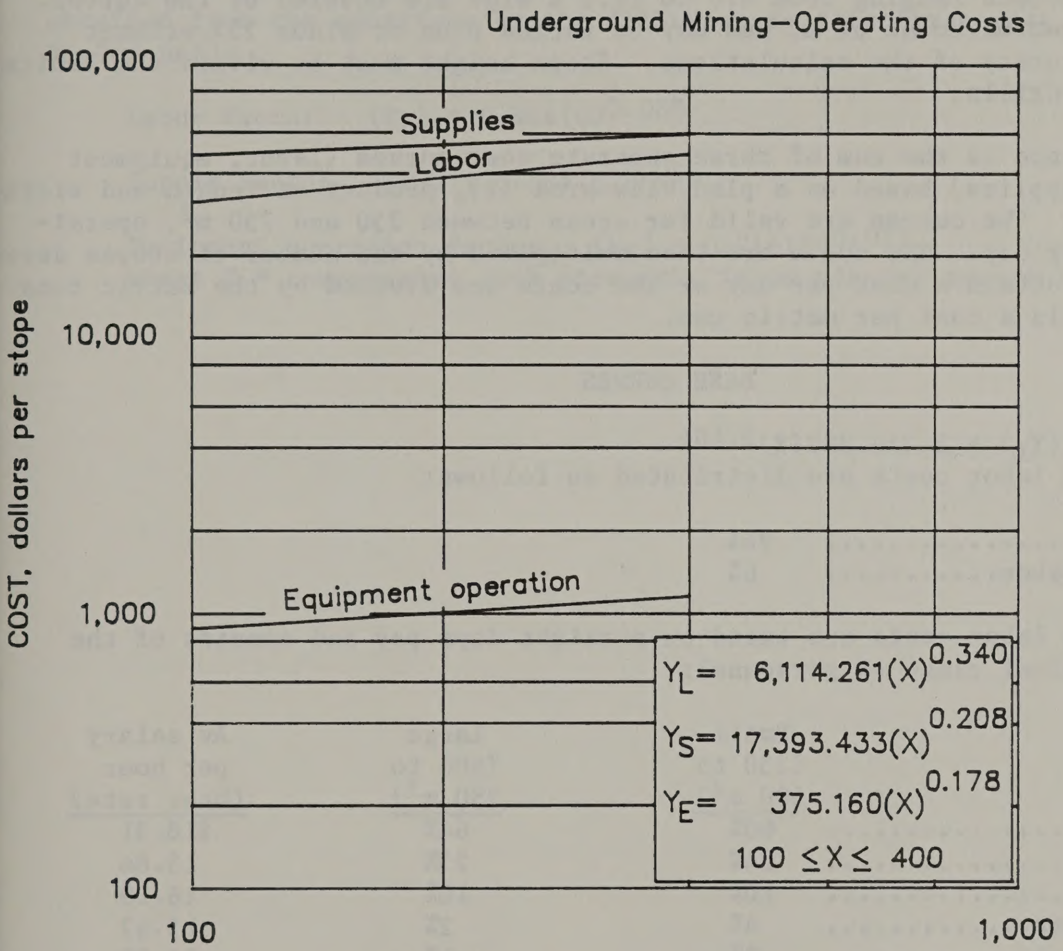
ADJUSTMENT FACTOR

Rock Hardness Factor Square set stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



$Y_L = 6{,}114.261(X)^{0.340}$

$Y_S = 17{,}393.433(X)^{0.208}$

$Y_E = 375.160(X)^{0.178}$

$100 \leq X \leq 400$

5.2.1.9.9. Stope preparation
SQUARE SET

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.1. PRODUCTION DEVELOPMENT

5.2.1.9.10. STOPE PREPARATION VERTICAL CRATER RETREAT

Items needed for preparation of a vertical crater retreat stope include a topsill cut, a bottom sill cut, and access drifts. The curves are based on the assumption that, during production, ore will be drawn from the bottom sill using remote controlled LHD's. Stopes ranging from 4.6 to 11.6 m wide are covered by the curves. Stope length is estimated at 61 m, but may be varied plus or minus 25% without affecting the accuracy of the calculations. Stope height must be within the limits of down-the-hole drills.

Total cost per stope is the sum of three separate cost curves (labor, equipment operation, and supplies) based on a plan view area (X), product of length and width, in square meters. The curves are valid for areas between 250 and 750 m^2, operating two shifts per day. The costs are then multiplied by the number of stopes developed per day to obtain a cost per day or the costs are divided by the metric tons per stope to obtain a cost per metric ton.

BASE CURVES

(L) Labor Cost $(Y_L) = 2{,}254.882(X)^{0.464}$
The operating labor costs are distributed as follows:

Direct labor................	94%
Maintenance labor...........	6%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (250 to 500 m^2)	Large (500 to 750 m^2)	Av salary per hour (base rate)
Miners......................	60%	64%	$18.31
Helpers.....................	24%	23%	13.86
LHD operators...............	10%	10%	16.09
Utility workers.............	4%	2%	15.42
Surveyors...................	2%	1%	15.08

The average wage for labor is $16.96 per worker-hour (including burden and average shift differential).

(S) Supply Cost $(Y_S) = 1{,}086.699(X)^{0.642}$
The supply cost consists of 51% blasting supplies, 20% steel items, 11% drill bits and steel, 10% ventilation materials, 5% contingency, and 3% electricity and miscellaneous items. Supplies necessary for the development of a vertical crater retreat stope include drill bits and steel, blasting agent, caps, water and compressed air pipe, ventilation ducting, electricity, and rockbolts.

(E) Equipment Cost $(Y_E) = 10.062(X)^{0.969}$
The equipment operating cost consists of 64% for maintenance and overhaul parts, 19% for tires, 11% for fuel, and 6% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment used in stope preparation for vertical crater retreat mining includes LHD's, jacklegs, auxiliary fans, and jumbo-mounted drifters.

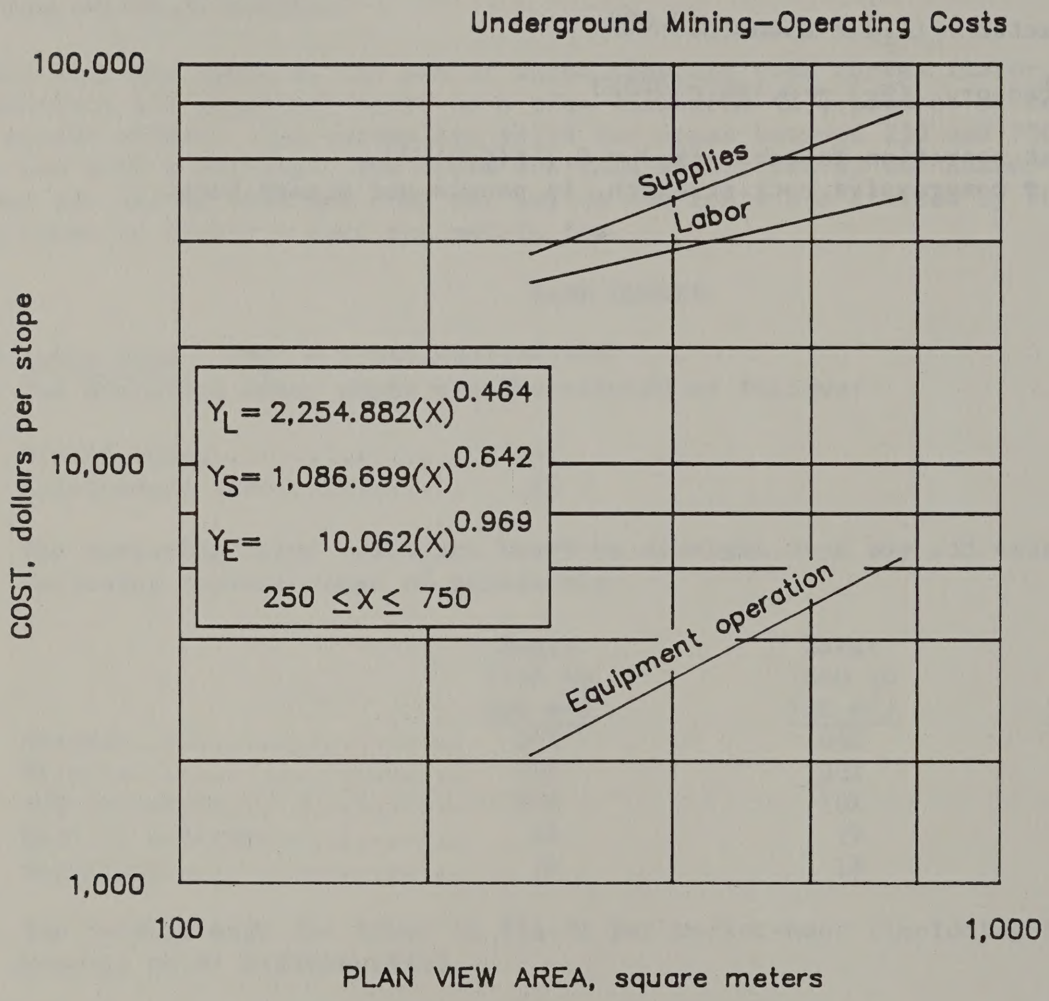
ADJUSTMENT FACTOR

Rock Hardness Factor Vertical crater retreat stope development costs are directly related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.404(C)^{0.089}$

Supply factor $(F_S) = 0.584(C)^{0.053}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.1.9.10. Stope preparation
VERTICAL CRATER RETREAT

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.1.1. BLOCK CAVING GRAVITY METHOD

Pure gravity block caving methods are best used when the ore is well fractured, and will break into fragments small enough to flow through a draw system without significant blockage. Productivity varies from 115 to 302 mt per worker-shift. Only the drawing of the ore during actual production is accounted for. Construction of grizzly drifts, crosscut drifts, panel drifts, and draw raises, as well as cave induction, re included in the stope preparation curves. Haulage of the ore from the stopes is covered in the haulage curves. Costs derived from the block caving curves apply to both block and panel caving methods.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 2,500 and 40,000 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 15.726(X)^{0.671}$
The operating labor costs are distributed as follows:

Direct labor................	100%
Maintenance labor...........	0%

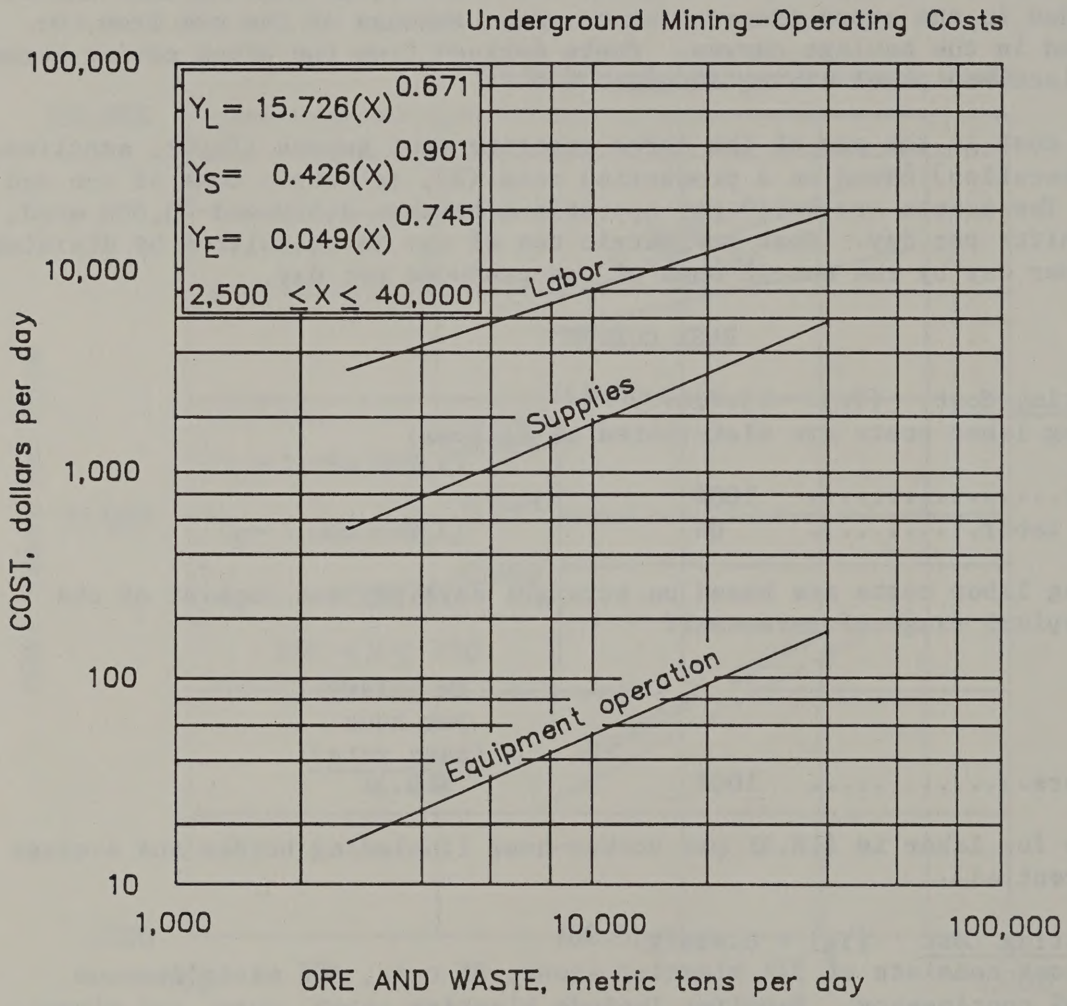
The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Hangup Workers..............	100%	$18.31

Average wage for labor is $18.31 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.426(X)^{0.901}$
The supply cost consists of 37% blasting agent, 8% caps, 50% miscellaneous items, and 5% contingency. Supplies include blasting agent, caps, and miscellaneous items used for secondary blasting and supplemental drift support.

(E) Equipment Operating Cost $(Y_E) = 0.049(X)^{0.745}$
The equipment operating cost consists of 94% for maintenance and overhaul parts and 6% for lubrication. Equipment for gravity block caving consists only of jackleg drills used to assist in secondary blasting.



5.2.2.1.1. Block caving
GRAVITY METHOD

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.1.2. BLOCK CAVING
LOAD-HAUL-DUMP METHOD

LHD block caving methods are used when the ore is not well fractured, but will cave. The ore often breaks into fragments too large to be handled by slushers, and secondary blasting can be excessive. Haul length for the LHD units is estimated at 100 m. Productivity varies from 67 to 160 mt per worker-shift. Only the drawing of the ore during actual production is accounted. Construction of grizzly drifts, LHD drifts, panel drifts, and draw raises, as well as cave induction, are included in the stope preparation curves. Haulage of the ore from LHD-fed production chutes is covered in the haulage curves. Costs derived from the block caving curves apply to both block and panel caving methods.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 2,500 and 40,000 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 22.650(X)^{0.692}$
The operating labor costs are distributed as follows:

Direct labor................	93%
Maintenance labor..........	7%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

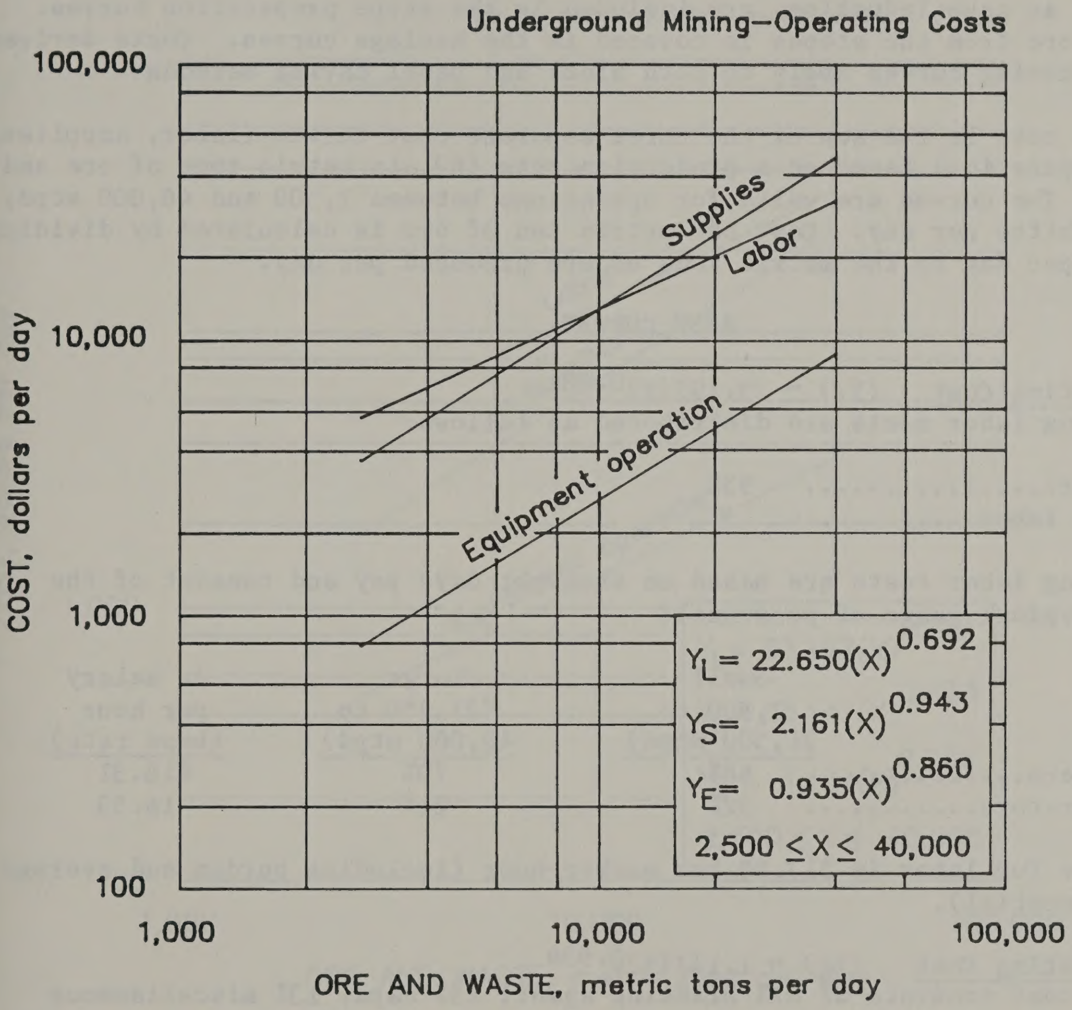
	Small (2,500 to 21,250 mtpd)	Large (21,250 to 40,000 mtpd)	Av salary per hour (base rate)
Hangup workers.............	78%	88%	$18.31
LHD operators..............	22%	12%	$16.53

Average wage for labor is $18.06 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.161(X)^{0.943}$
The supply cost consists of 72% blasting agent, 17% caps, 6% miscellaneous items, and 5% contingency. Supplies include blasting agent, caps, and miscellaneous items used for secondary blasting and supplemental drift support.

(E) Equipment Operating Cost $(Y_E) = 0.935(X)^{0.860}$
The equipment operating cost consists of 49% for maintenance and overhaul parts, 28% for tires, 18% for fuel, and 5% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. The equipment

used in LHD block caving includes LHD units for intermediate ore handling, and jackleg drills for secondary blasting.



5.2.2.1.2. Block caving
L.H.D. METHOD

5.2.2.1.3. BLOCK CAVING
SLUSHER METHOD

Slusher block caving methods are used when the ore is reasonably well fractured and breaks into fragments that can be handled by slushers. Productivity varies from 70 to 181 mt per worker-shift. Only the drawing of the ore during actual production is accounted. Construction of grizzly drifts, slusher drifts, panel drifts, and draw raises, as well as cave induction, are included in the stope preparation curves. Haulage of the ore from the stopes is covered in the haulage curves. Costs derived from the block caving curves apply to both block and panel caving methods.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 2,500 and 40,000 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 23.197(X)^{0.681}$
The operating labor costs are distributed as follows:

Direct labor................	95%
Maintenance labor...........	5%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

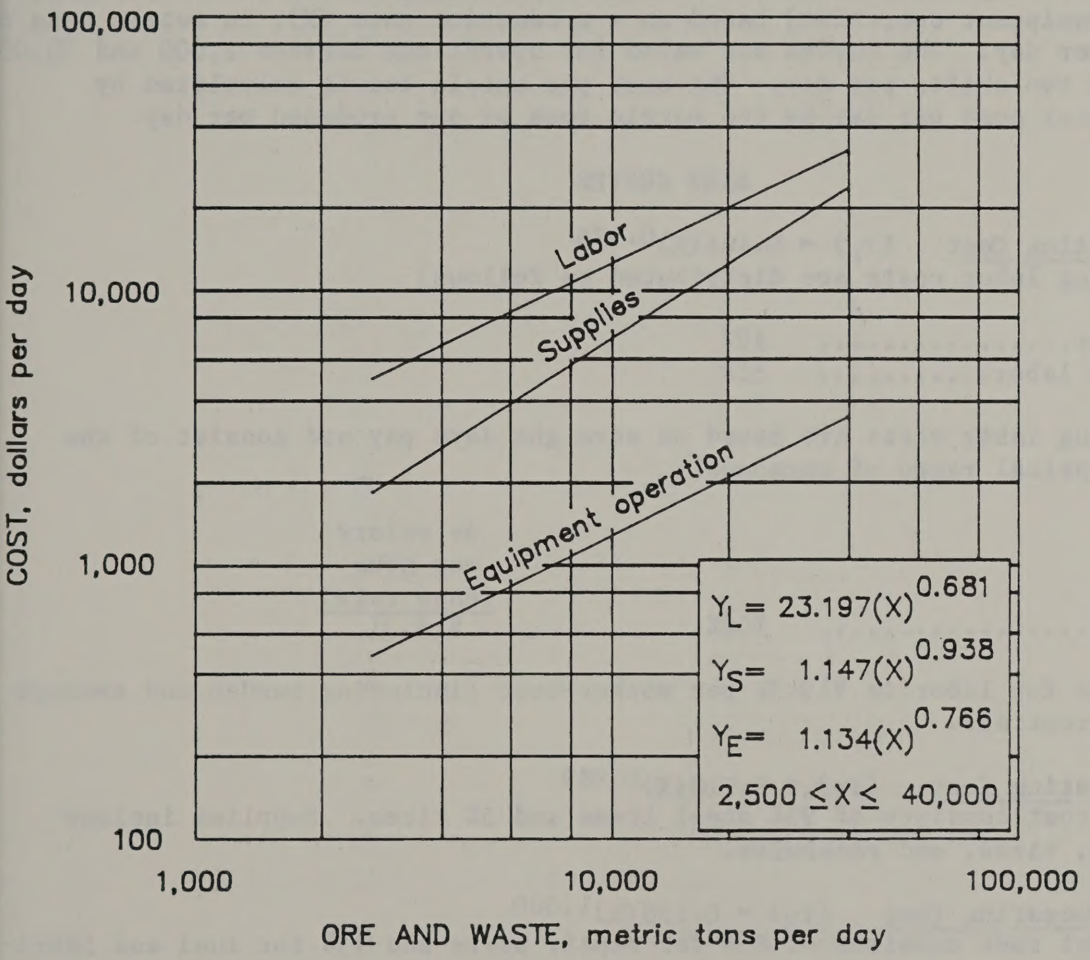
	Small (2,500 to 21,500 mtpd)	Large (21,250 to 40,000 mtpd)	Av salary per hour (base rate)
Hangup workers..............	68%	79%	$18.31
Slusher operators...........	32%	21%	16.53

Average wage for labor is $17.90 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.147(X)^{0.938}$
The supply cost consists of 67% blasting agent, 15% caps, 13% miscellaneous items, and 5% contingency. Supplies include blasting agent, caps, and miscellaneous items used for secondary blasting and supplemental drift support.

(E) Equipment Operating Cost $(Y_E) = 1.134(X)^{0.766}$
The equipment operating cost consists of 55% for maintenance and overhaul parts, 39% for electricity, and 6% for lubrication. The equipment used in slusher block caving includes slushers for inter- mediate ore handling, and jackleg drills for secondary blasting.

Underground Mining—Operating Costs



5.2.2.1.3. Block caving
SLUSHER METHOD

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.2. CONTINUOUS MINING

The continuous miner curve is based on using continuous miners, shuttle cars, and rock bolters. Production rates average 100 mt per worker-shift. Only the cutting of the ore and haulage by shuttle car to a nearby conveyor loading point (approximately 100 m) are covered by the curve. Haulage by conveyor and other services are covered in other curve sections.

The total daily cost per day is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 2,000 and 30,000 mtpd, operating two shifts per day. The cost per metric ton is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 0.464(X)^{0.975}$
The operating labor costs are distributed as follows:

Direct labor................	49%
Maintenance labor...........	51%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	100%	$18.31

Average wage for labor is $18.31 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.718(X)^{0.989}$
The supply cost consists of 95% steel items and 5% tires. Supplies include cutter bits, tires, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.130(X)^{1.000}$
The equipment cost consists of 85% for repair parts and 15% for fuel and lubrication. The equipment operating curve covers repair parts, fuel, and lubrication for the continuous miners, shuttle cars, and rock bolters.

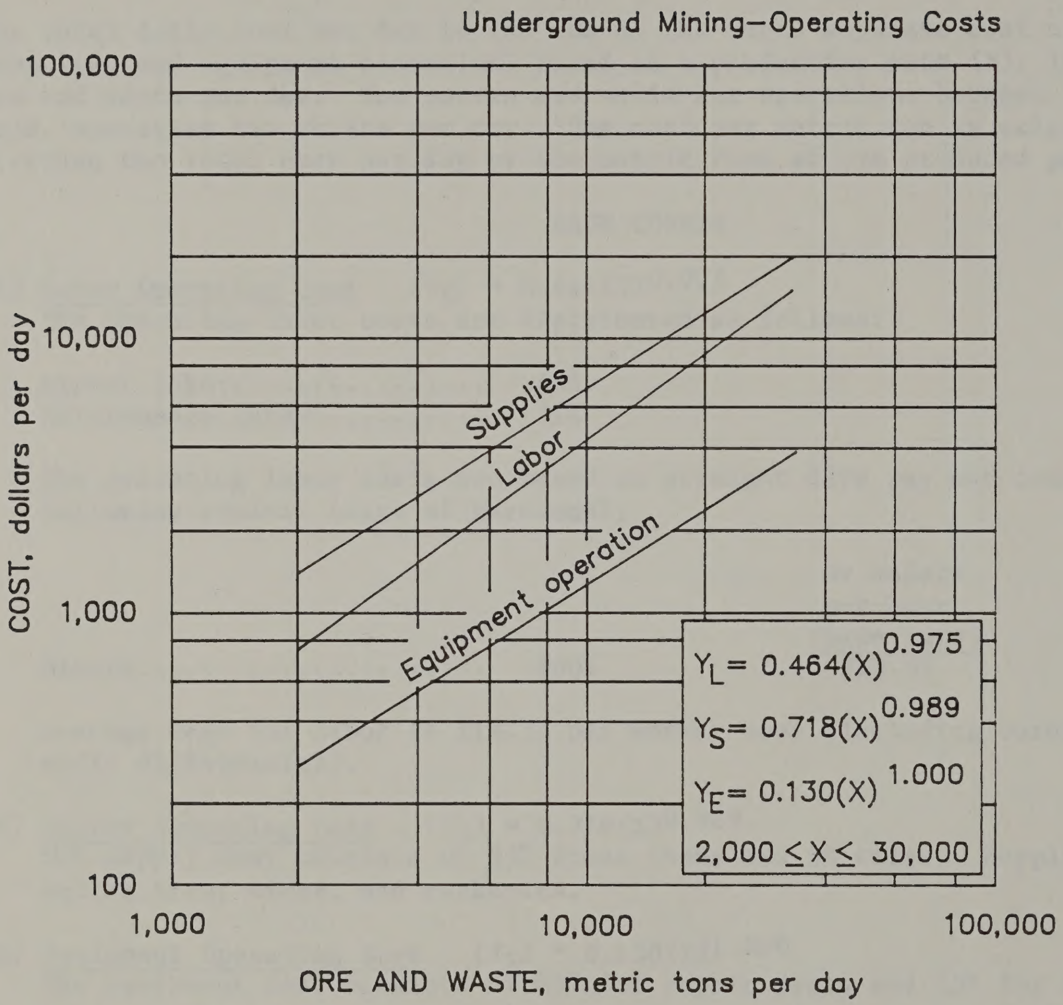
ADJUSTMENT FACTOR

Rock Hardness Factor Continuous mining productivity is related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.2.2. Continuous mining

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.3. CUT AND FILL

The cut-and-fill stope curve is based on using jacklegs for drilling and rock bolting. Costs include excavation of the ore, slushing to chutes, and sandfill operations including chute and manway extensions. Production rates vary from 6 to 12 mt per worker-shift. Only the drilling and blasting of ore during actual production are accounted for in this curve. Access drift construction and service installation are covered in the stope preparation curve. Haulage and other services are covered in separate sections.

The total daily cost per day is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 100 and 8,000 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 49.858(X)^{0.858}$
The operating labor costs are distributed as follows:

Direct labor..........	98%
Maintenance labor.....	2%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners................	80%	$18.31
Helpers...............	20%	13.86

Average wage for labor is $17.42 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.970(X)^{0.976}$
The supply cost consists of 26% explosives, 24% steel items, 32% timber, and 18% miscellaneous items. Supplies include drill bits and steel, powder, caps, timber, sandfill, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.585(X)^{0.974}$
The equipment operating cost consists of 92% for repair parts and 8% for lubrication. The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for the jacklegs, slushers, and tuggers.

ADJUSTMENT FACTORS

Rock Hardness Factor Cut-and-fill mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

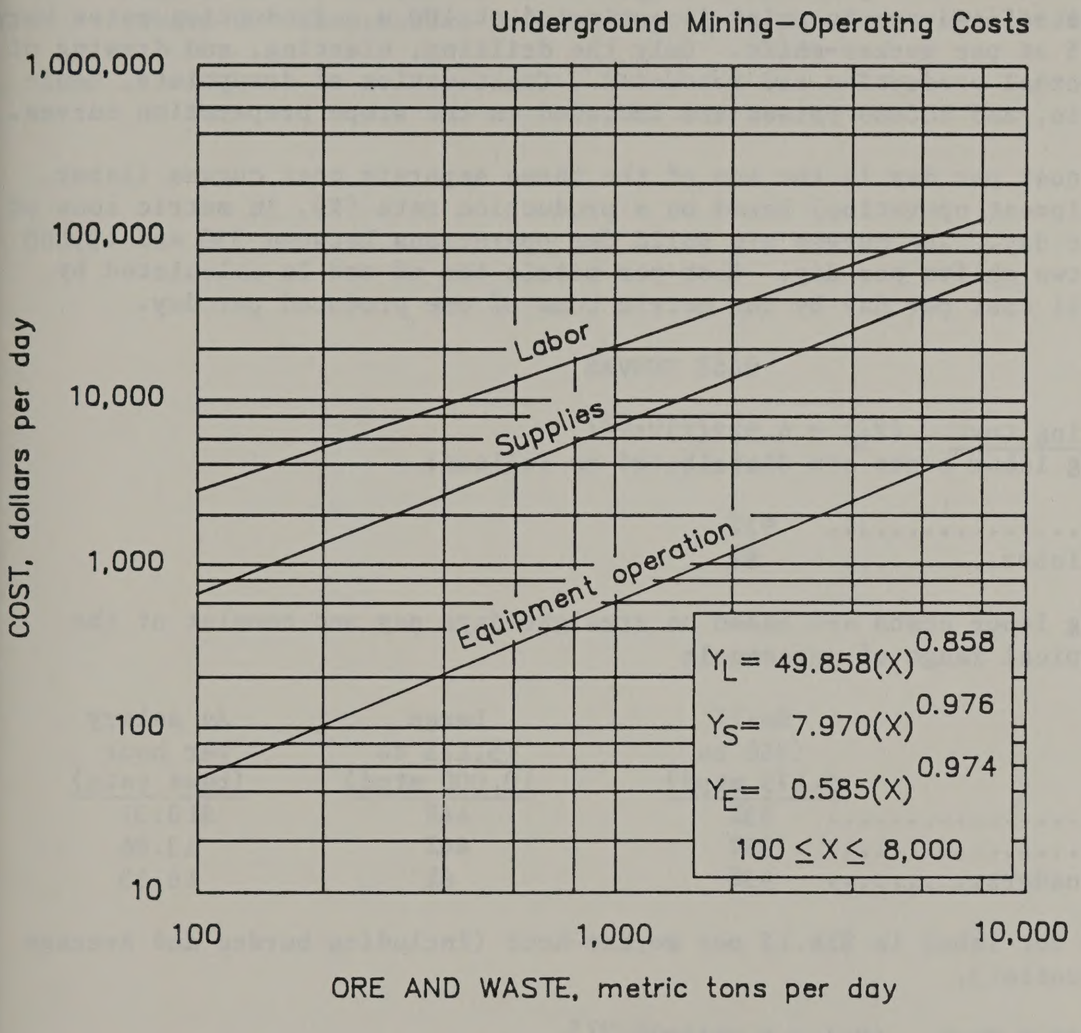
Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Width Factor The curve is based on a stope 1.83 m wide with varying lengths. For stopes from 1.0 to 6.1 m wide, multiply the costs obtained from the curves by the following factor:

Width factor $(F_W) = 1.205(W)^{-0.315}$
where W = width of stope, in meters.



5.2.2.3. Cut and fill

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.4. LONGHOLE

The cost curves are based on longhole stope mining using deephole ring drills for all drilling, and LHD units for drawing broken ore from a series of draw points. Costs for mining vein widths of 3.5 m and wider can be determined using these curves. Narrow or irregular veins usually do not avail themselves to longhole methods. The curves cover a production range of 350 to 10,000 mtpd. Average haul distance to a central conveyance point is estimated at 100 m. Production rates vary from 60.6 to 94.5 mt per worker-shift. Only the drilling, blasting, and drawing of the ore during actual production are accounted. Construction of drawpoints, haulageways, sublevels, and access raises are included in the stope preparation curves.

The total daily cost per day is the sum of the three separate cost curves (labor, supplies and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 350 and 10,000 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 4.922(X)^{0.877}$

The operating labor costs are distributed as follows:

Direct labor................	92%
Maintenance labor...........	8%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (350 to 5,175 mtpd)	Large (5,175 to 10,000 mtpd)	Av salary per hour (base rate)
Miners......................	33%	44%	$18.31
Helpers.....................	33%	44%	13.86
Production loaders..........	33%	8%	16.53

Average wage for labor is $16.15 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.764(X)^{0.973}$

The supply cost consists of 40% blasting materials, 37% drill bits and steel, 14% miscellaneous items, and 9% contingency. Supplies include drill bits, steel, ANFO, primers, caps, detonation cord, and miscellaneous items.

(E) Equipment Operating Cost $(Y_E) = 0.316(X)^{0.976}$

The equipment cost consists of 52% for maintenance and overhaul parts, 26% for tires, 17% for fuel, and 5% for lubrication. The equipment curve covers maintenance and overhaul parts, tires, fuel, and lubrication. Equipment for longhole stope mining includes LHD units, deep-hole drills, and ring drill carriers.

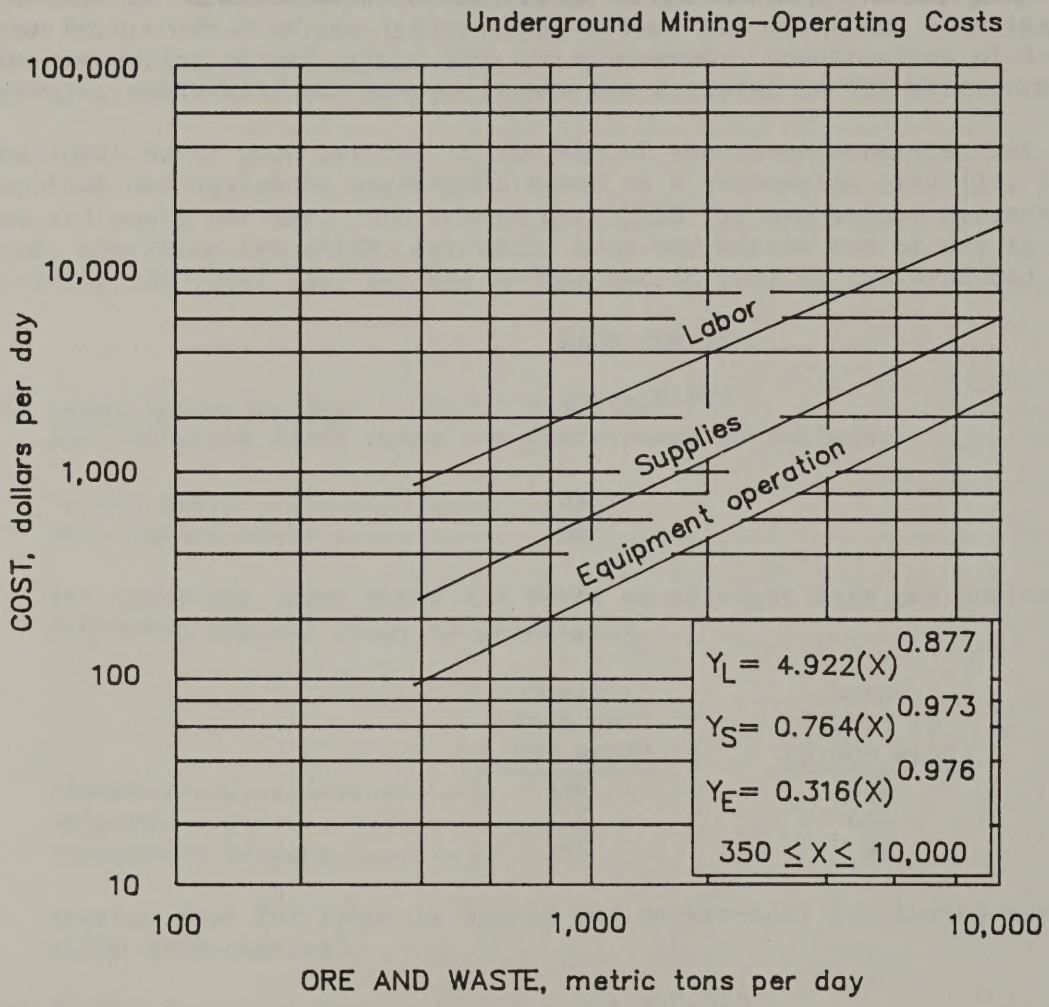
ADJUSTMENT FACTOR

Rock Hardness Factor Longhole mining is related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.2.4. Longhole

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.5. RESUING

Resuing is a method of stoping in which the ore is broken and removed first and then the waste or vice versa; usually the one, that breaks easier is blasted first. The broken waste is left in stope as filling and the ore is broken down on flooring laid on the fill to prevent mixing of ore and waste. Resuing is applicable where the ore is not frozen to the stope walls and works best if there is considerable difference between the hardness of the ore and the wall rocks. The methods is labor intensive and is rarely practiced in North America except in very high-grade narrow vein-type deposits of higher economic values. The productivity in the stopes using a resuing method of stoping is generally low when compared with other methods of mining.

Productivity varies from 1.7 to 4.2 mt per worker shift in the stope. The average vein width considered for 20- 200- and 400-mtpd operation is 0.46 m (18 in), 0.61 m (24 in) and 0.76 m (30 in) respectively. The minimum stoping width assumed is 1.2 m (4.0 ft). Only the drawing of the ore during actual production, with partial drawing of waste when required, is accounted.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore per day. The curves are valid for operations between 20 and 450 mt, operating two shifts per day, 5 days a week. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

Base Curves

(L) Labor Operating Cost $(Y_L) = 219.542(X)^{0.695}$
The operating labor costs are distributed as follows:

Direct labor................	96%
Maintenance labor...........	4%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	50%	$18.31
Slusher operators...........	50%	16.53

Average wage for labor is $17.42 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 12.157(X)^{1.050}$
The supply cost consists of 21% powder, 21% caps, 15% rockbolts, 33% timber, and 10% miscellaneous items. Supplies include powder and caps for blasting, rockbolts and timber for ground support, and miscellaneous items such as blasting wires, hangers, small tools, and material waste.

(E) Equipment Operating Cost $(Y_E) = 0.866(X)^{0.823}$
The equipment operating curve consists of 80% for maintenance and repair parts for slushers, 12% for jacklegs, and 8% for lubricants.

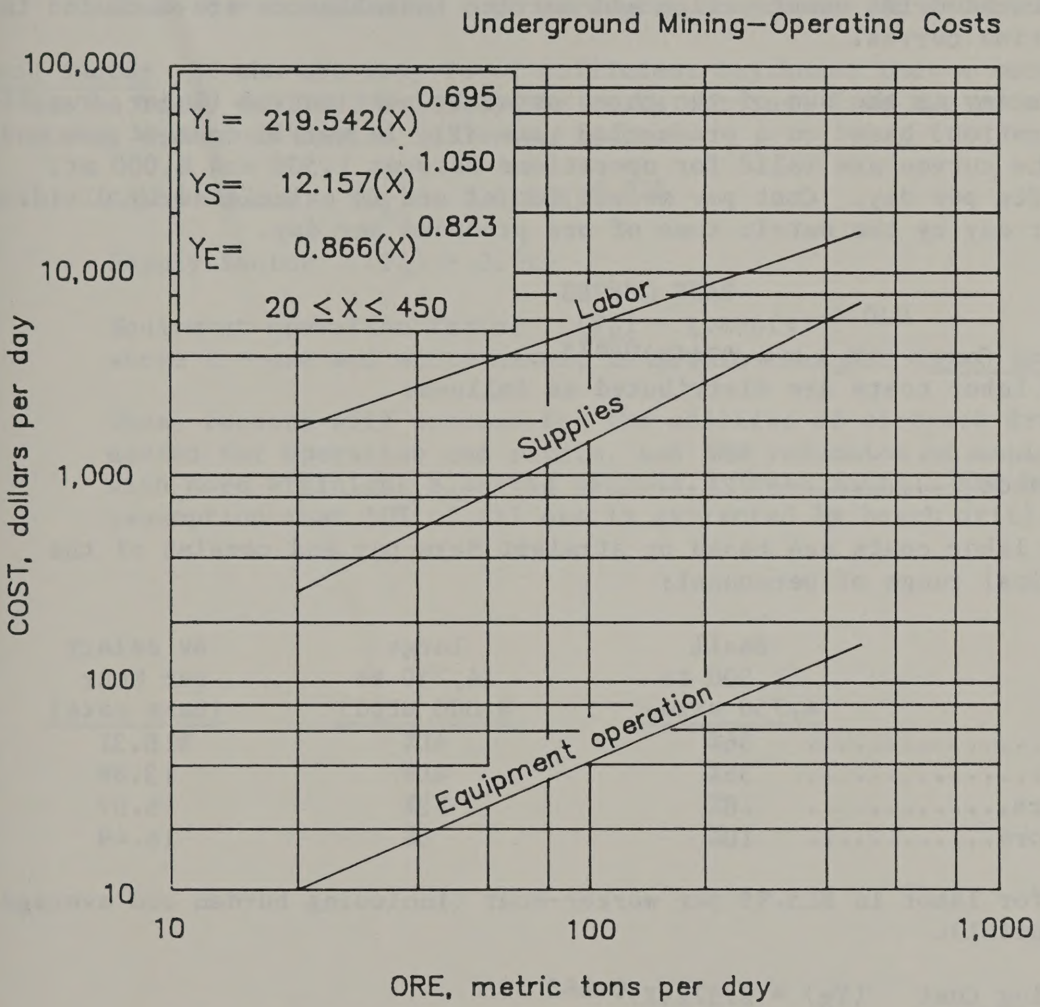
ADJUSTMENT FACTOR

Rock Hardness Factor Resuing mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.403(C)^{0.090}$

Supplies factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



Underground Mining—Operating Costs

5.2.2.5. Resuing

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.6. ROOM AND PILLAR
MEDIUM TO HARD ROCK

The cost curves are based on room and pillar mining using jumbo-mounted drifters for all drilling, and front-end loaders for transferring broken ore to rubber-tired haulage trucks at the face. Production rates vary from 82 to 99 mt per worker-shift. Only the drilling, blasting, and loading of the ore during actual production are accounted. Access drift construction and service installation are included in the stope preparation curves.

The total cost per day is the sum of the three separate cost curves (labor, supplies and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 1,500 and 8,000 mt, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 4.074(X)^{0.875}$
The operating labor costs are distributed as follows:

Direct labor................	98%
Maintenance labor..........	2%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (1,500 to 4,750 mtpd)	Large (4,750 to 8,000 mtpd)	Av salary per hour (base rate)
Miners......................	36%	41%	$18.31
Helpers.....................	36%	41%	13.86
Utility workers.............	18%	12%	16.07
Loader operators............	10%	6%	16.49

Average wage for labor is $15.95 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.572(X)^{0.863}$
The supply cost consists of 48% blasting supplies, 26% drill bits and steel, 13% rock support materials, 8% miscellaneous items, and 5% contingency. Supplies necessary for medium to hard rock room and pillar mining include drill bits and steel, blasting agent, caps, rockbolts, and miscellaneous items.

(E) Equipment Operating Cost $(Y_E) = 0.079(X)^{0.967}$
The equipment operating cost consists of 54% for maintenance and overhaul parts, 26% for fuel, 12% for tires, and 8% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment for medium to hard rock room and pillar mining includes jumbo-mounted drifters, front-end loaders, air leg drills, and powder buggies.

ADJUSTMENT FACTORS

Rock Hardness Factor Room and pillar mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

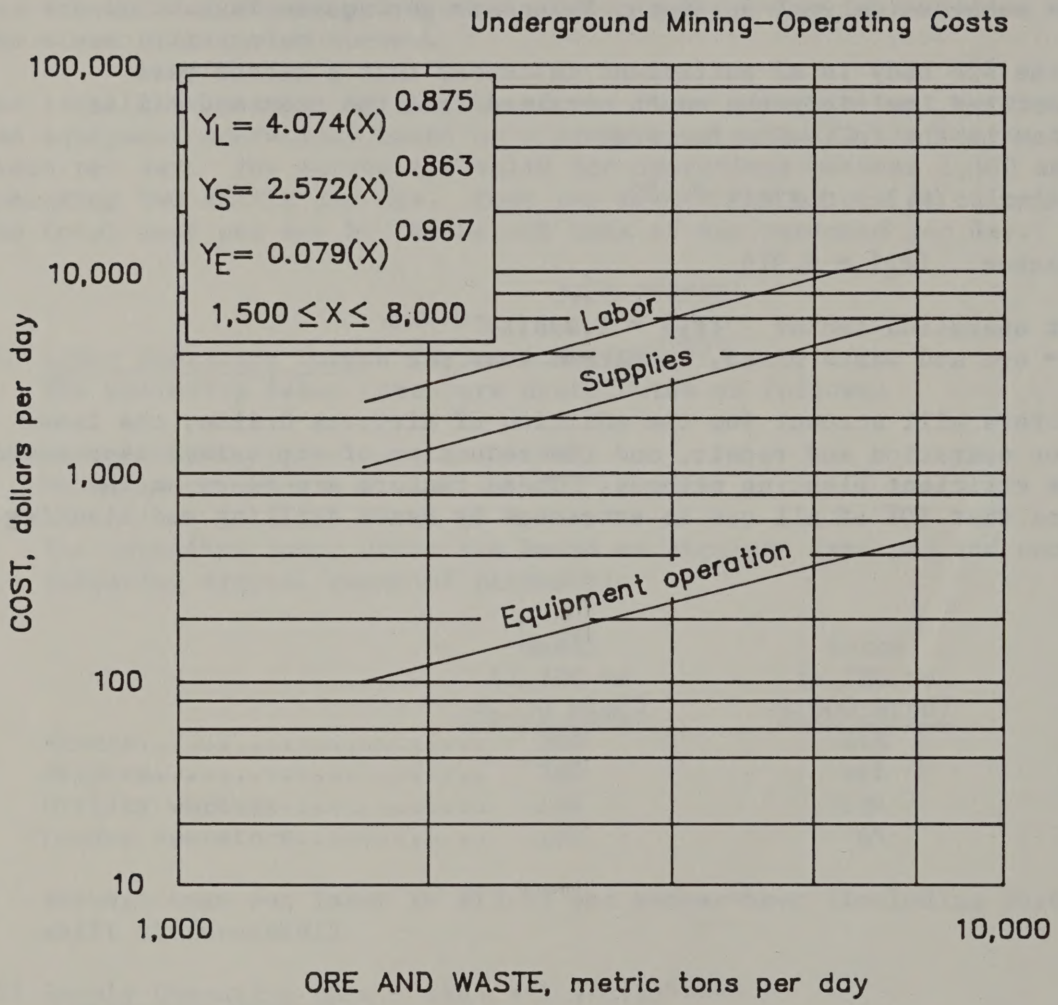
Bench Factor If the ore body is of sufficient thickness that a second pass can be bench drilled, multiply the costs obtained from the room and pillar mining equations by the following factors:

Labor factor $(F_L) = 0.872(X)^{0.020}$

Supply factor $(F_S) = 0.910$

Equipment operation factor $(F_E) = 1.498(X)^{-0.013}$
where X = ore and waste mined, in metric tons per day.

These factors will account for the addition of airtrack drills, the labor needed for operation and repair, and the reduction of explosives associated with more efficient blasting methods. These factors are based on the assumption that 50% of all ore is extracted by bench drilling and blasting.



5.2.2.6. Room and pillar—medium to hard rock

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.7. ROOM AND PILLAR
NONMETALLIC SOFT ROCK

The cost curves are based on room and pillar mining using jumbo-mounted drifters for all drilling, and LHD units, or continuous loaders with shuttle cars, for handling broken ore. The average haul length to an access conveyor is estimated at 100 m. Production rates vary from 102 to 136 mt per worker-shift. Only the drilling, blasting, loading, and hauling of the ore to an access conveyor during actual production are accounted. Service and conveyor installation and access drift construction are included in the stope preparation curves.

The total cost per day is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 800 and 9,500 mtpd, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 3.186(X)^{0.894}$
The operating labor costs are distributed as follows:

Direct labor................	87%
Maintenance labor..........	13%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (800 to 5,150 mtpd)	Large (5,150 to 9,500 mtpd)	Av salary per hour (base rate)
Miners......................	38%	38%	$18.27
Loader operators...........	38%	25%	13.50
Motor operators............	-	25%	16.06
Utility workers............	24%	12%	16.06

Average wage for labor is $17.01 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.936(X)^{0.991}$
The supply cost consists of 26% drill bits and steel, 25% blasting supplies, 24% rock support materials, 12% electricity, 8% miscellaneous items, and 5% contingency. Supplies necessary for nonmetallic room and pillar mining include drill bits and steel, blasting agent, caps, rockbolts, electricity, and miscellaneous items.

(E) Equipment Operating Cost $(Y_E) = 2.159(X)^{0.723}$
The equipment operating cost consists of 68% for maintenance and overhaul parts, 18% for tires, 11% for lubrication, and 3% for fuel. The equipment curve covers

maintenance and overhaul parts, fuel, tires, and lubrication. Equipment for nonmetallic room and pillar mining includes jumbo-mounted drifters, roof bolters, powder buggies, undercutters, LHD's or continuous loaders with shuttle cars, and transformers.

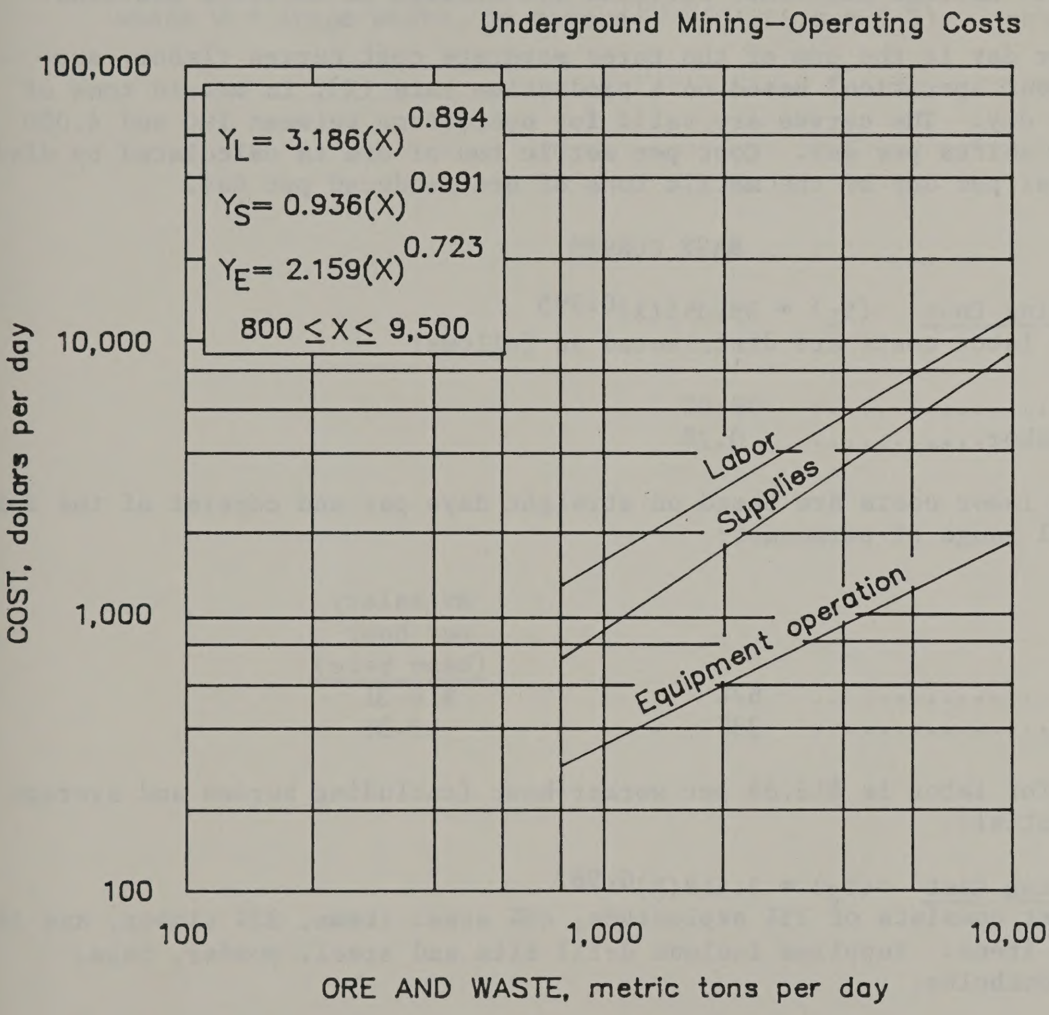
ADJUSTMENT FACTOR

Rock Hardness Factor Room and pillar mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

Equipment operation factor $(F_E) = 0.715(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.



5.2.2.7. Room and pillar—nonmetallic soft rock

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.8. SHRINKAGE

The shrinkage stope curve is based on using stopers for drilling and jacklegs for rock bolting. Production rates vary from 3 to 10 mt per worker-shift. Only the drilling and blasting of ore during actual production are accounted for in this curve. Access drift construction and service installation are covered in the stope preparation curve. Haulage and other services are covered in separate sections.

The total cost per day is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 100 and 4,000 mt, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 39.395(X)^{0.895}$
The operating labor costs are distributed as follows:

Direct labor................	99.8%
Maintenance labor...........	0.2%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	67%	$18.31
Helpers.....................	33%	13.86

Average wage for labor is $16.84 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 3.549(X)^{0.987}$
The supply cost consists of 25% explosives, 48% steel items, 22% timber, and 5% miscellaneous items. Supplies include drill bits and steel, powder, caps, timber, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.086(X)^{0.894}$
The equipment operating cost consists of 93% for repair parts and 7% for lubrication. The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for the stopers and jacklegs.

ADJUSTMENT FACTORS

Rock Hardness Factor Shrinkage mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

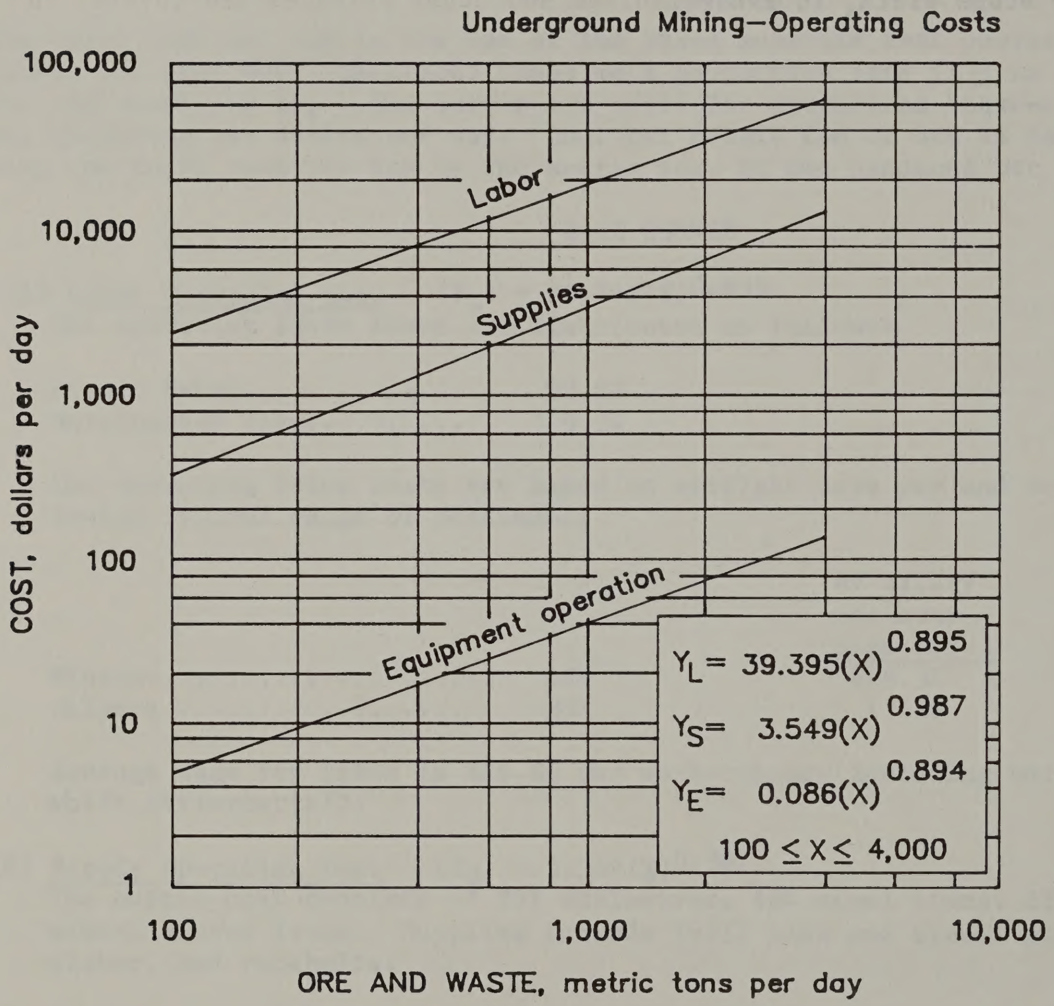
Labor factor $(F_L) = 0.399(C)^{0.091}$

Supply factor $(F_S) = 0.585(C)^{0.053}$

Equipment operation factor $(F_E) = 0.717(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Width Factor The curve is based on a stope 1.83 m wide with varying lengths. For stopes from 1.0 to 6.1 m wide, multiply the costs obtained from the curves by the following factor:

Width factor $(F_W) = 1.353(W)^{-0.500}$
where W = stope width, in meters.



5.2.2.8. Shrinkage

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.9. SQUARE SET

The square set stope curve is based on using jacklegs for drilling and rock bolting. Costs include excavation of the ore, slushing to chutes, and timber installation including chute and manway extensions. Production rates vary from 4 to 8 mt per worker-shift. Only the drilling and blasting of ore during actual production are accounted for in this curve. Access drift construction and service installation are covered in the stope preparation curve. Haulage and other services are covered in separate sections.

The total cost per day is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 20 and 200 mt, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 60.332(X)^{0.839}$

The operating labor costs are distributed as follows:

Direct labor................	99%
Maintenance labor...........	1%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Miners......................	100%	$18.31

Average wage for labor is $18.31 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 13.246(X)^{0.890}$

The supply cost consists of 22% explosives, 13% steel items, 59% timber, and 6% miscellaneous items. Supplies include drill bits and steel, powder, caps, timber, and rockbolts.

(E) Equipment Operating Cost $(Y_E) = 0.750(X)^{0.902}$

The equipment operating cost consists of 92% for repair parts and 8% for lubrication. The equipment operating curve covers daily maintenance and repair, repair parts, and lubrication for the jacklegs, slushers, and tuggers.

ADJUSTMENT FACTORS

Rock Hardness Factor Square set mining costs are related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table

A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

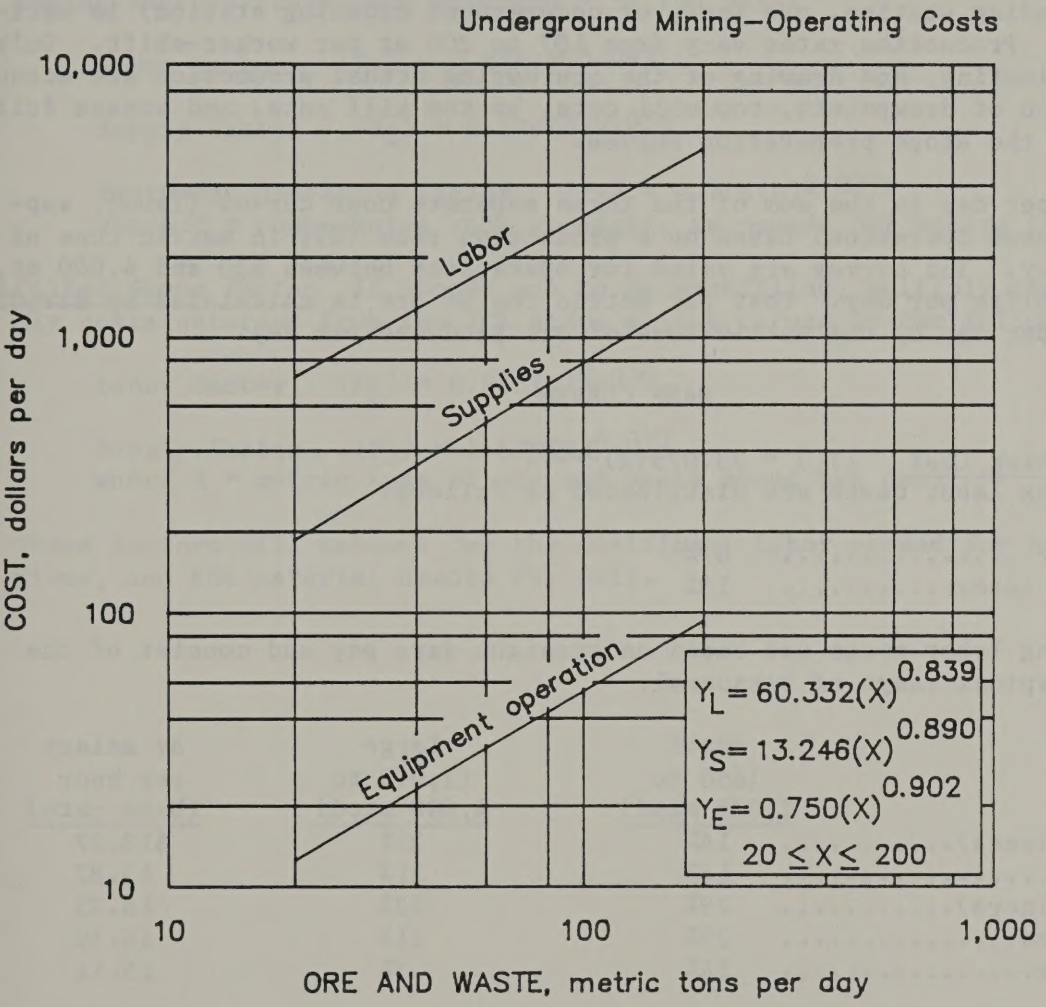
Labor factor $(F_L) = 0.403(C)^{0.090}$

Supply factor $(F_S) = 0.590(C)^{0.052}$

Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Width Factor The curve is based on a stope 7.2 m wide with varying lengths. For stopes from 1.0 to 7.2 m wide, multiply each curve value by the following factor:

Width factor $(F_W) = 1.50(W)^{-0.205}$
where W = stope width, in meters.



5.2.2.9. Square set

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.2. MINING

5.2.2.10. VERTICAL CRATER RETREAT

The cost curves are based on VCR stope mining using down-hole drills for all drilling, and LHD units for drawing broken ore. The curves apply to any mining system in which large-diameter blastholes are loaded from the top sill, and ore is blasted into an undercut. This includes vertical crater retreat, vertical retreat mining, and end slicing to a drop raise. Average haul distance to a central conveyance point (truck loading station, ore pass, or underground crushing station) is estimated at 200 m. Production rates vary from 107 to 200 mt per worker-shift. Only the drilling, blasting, and drawing of the ore during actual production are accounted. Construction of drawpoints, top sill cuts, bottom sill cuts, and access drifts are included in the stope preparation curves.

The total cost per day is the sum of the three separate cost curves (labor, supplies and equipment operation) based on a production rate (X), in metric tons of ore and waste per day. The curves are valid for operations between 650 and 4,000 mt, operating two shifts per day. Cost per metric ton of ore is calculated by dividing the total cost per day by the metric tons of ore produced per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 23.075(X)^{0.595}$
The operating labor costs are distributed as follows:

Direct labor................	87%
Maintenance labor...........	13%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (650 to 2,975 mtpd)	Large (2,975 to 4,000 mtpd)	Av salary per hour (base rate)
Drillers (miners)...........	14%	21%	$18.27
Helpers.....................	14%	21%	13.82
Blasters (miners)...........	29%	42%	18.35
LHD operators...............	29%	11%	16.50
Lead blaster................	14%	5%	15.11

Average wage for labor is $16.93 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.152(X)^{0.947}$
The supply cost consists of 69% blasting supplies, 13% drill bits and steel, 9% miscellaneous items, and 9% contingency. Supplies necessary for VCR mining include drill bits, drill steel, blasting agent, primers, caps, detonation cord, caristrap, timber, and miscellaneous items.

(E) Equipment Operating Cost $(Y_E) = 1.502(X)^{0.792}$
The equipment operating cost consists of 44% for maintenance and overhaul parts, 33% for fuel, 16% for tires, and 7% for lubrication. The equipment curve covers maintenance and overhaul parts, fuel, tires, and lubrication. Equipment for VCR stope mining includes down-hole drills, air track drill carriers, booster compressors, LHD units, and bit grinders.

ADJUSTMENT FACTORS

Rock Hardness Factor VCR productivity is related to rock hardness. If the compressive strength of the rock is known, or an estimate can be made from table A-1 in the appendix, multiply the costs obtained from the equations by the following factors (base rock strength = 31,700 psi):

Labor factor $(F_L) = 0.388(C)^{0.093}$

Supply factor $(F_S) = 0.579(C)^{0.054}$

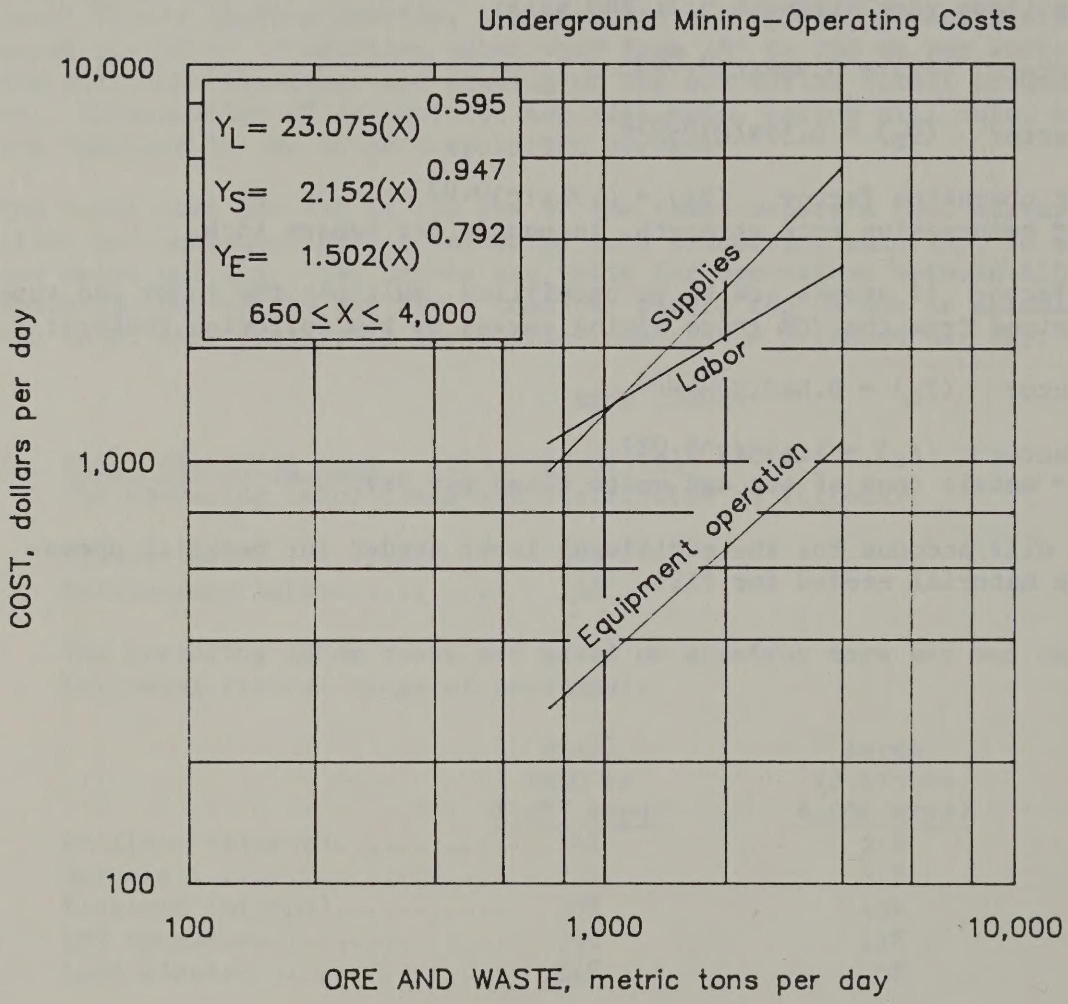
Equipment operation factor $(F_E) = 0.716(C)^{0.033}$
where C = compressive rock strength, in pounds per square inch.

Backfilled Stope Factor If stopes are to be backfilled, multiply the labor and supply costs obtained from the VCR stope mining curves by the following factors:

Labor factor $(F_L) = 0.863(X)^{0.030}$

Supply factor $(F_S) = 1.635(X)^{0.027}$
where X = metric tons of ore and waste mined per day.

These factors will account for the additional labor needed for backfill operations, and the material needed for fill.



5.2.2.10. Vertical crater retreat

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.1. HOISTING

Mine hoist operating costs, as determined in this section, are based on metric tons of ore and waste hoisted per hour from a specific depth on a two-shift-per-day schedule. When analyzing the hoisting system, the estimator should consider the following:

1. Double-drum hoists are applicable to multilevel hoisting for all sizes of mines.
2. Friction hoists are applicable for deep level (+915 m) and/or single level hoisting.
3. Mines that hoist over 4,000 mtpd often have more than one hoist (i.e., one hoist may haul ore and waste and one hoist may be used for servicing the mine). The costs are only applicable for one hoist. If more than one hoist is required, recalculate the curve(s) for each additional hoist (see ADJUSTMENTS for service hoists).
4. Mines that hoist over 20,000 mtpd typically have more than one production hoist in conjunction with at least one service hoist.
5. In choosing the hoisting system it is best to remember that these facilities are usually designed for a higher capacity than required. This is especially true for smaller mines or mines anticipating an increase in capacity (i.e., a hoist operating at 100 mtph may have a design capacity of 200 mtph).
6. Single hoist mines typical hoist muck for about 80% of the daily schedule (i.e., 13 h of a 16-h work day), the remaining 20% of the schedule is devoted to transporting personnel and supplies and performing maintenance. Mines serviced by more than one production hoist typically hoist muck about 90% of the daily schedule.

The curves show costs for double-drum and friction hoists and are based on hoisting from 914 m (3,000 ft).

The total cost per hour is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on hoist capacity (X), in metric tons material, per hour. The curves are valid for operations between 100 and 800 mt, operating two shifts per day. The total cost per day is the sum of the equipment operation, labor, and supply curves multiplied by the number of hours of operation daily.

BASE CURVES

(L) Labor Operating Costs $(Y_{L\ DOUBLE\text{-}DRUM}) = 860+[0.036(X)^{1.000}]$
$(Y_{L\ FRICTION}) = 860+[0.031(X)^{0.990}]$

The operating labor costs are distributed as follows:

Direct labor................	99%
Maintenance labor...........	1%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Hoist operator.............	34%	\$18.67
Cager......................	34%	18.11
Assistant cager............	32%	16.33

Average wage for labor is \$17.54 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_{S\ \mathrm{DOUBLE\text{-}DRUM}}) = 5.280(X)^{0.994}$
$(Y_{S\ \mathrm{FRICTION}}) = 4.485(X)^{0.983}$
The supply costs consists of 95% electric power and 5% wire rope replacement.

(E) Equipment Operating Costs $(Y_{E\ \mathrm{DOUBLE\text{-}DRUM}}) = 0.036(X)^{1.000}$
$(Y_{E\ \mathrm{FRICTION}}) = 0.031(X)^{0.990}$
The equipment operating cost consist of 80% for repair and maintenance parts and 20% for lubrication.

ADJUSTMENT FACTORS

Depth Factor To determine operating costs for hoisting facilities whose maximum hoisting depth varies from 914 m (3,000 ft), multiply the costs obtained from the supply and equipment operation curves by the following factors:

Double-drum hoist:
Supply factor $(Y_{S\ \mathrm{DOUBLE\text{-}DRUM}}) = 0.0009(D)^{1.032}$

Equipment operation factor $(Y_{E\ \mathrm{DOUBLE\text{-}DRUM}}) = 0.001(D)^{1.019}$
where D = maximum hoisting depth from the surface, in meters.

Friction hoist:
Supply factor $(Y_{S\ \mathrm{FRICTION}}) = 0.005(D)^{0.768}$

Equipment operation factor $(Y_{E\ \mathrm{FRICTION}}) = 0.007(D)^{0.729}$
where: D = maximum hoisting depth from the surface, in meters.

Shift Factor If hoists are operated one shift per day decrease costs 50%. If hoists are operated three shifts per day, increase costs 50%.

Hoist Factor Under the following conditions multiply the labor cost obtained from the curves by the following factors:

If a hoist is used for production hoisting only:
Labor factor $(F_L) = 0.69$

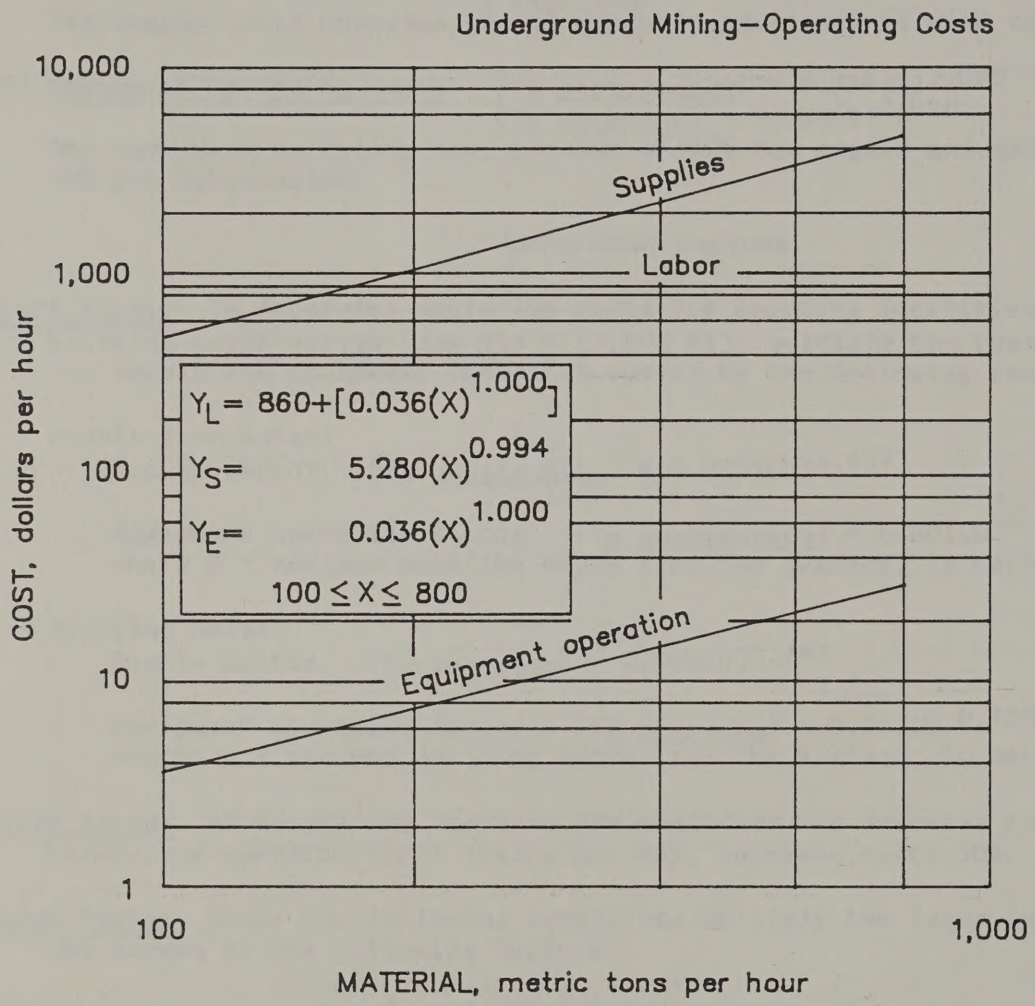
If a fully automatic hoist is used:
Labor factor $(F_L) = 0.71$

If a fully automatic hoist is used for production hoisting only:
Labor factor $(F_L) = 0.40$

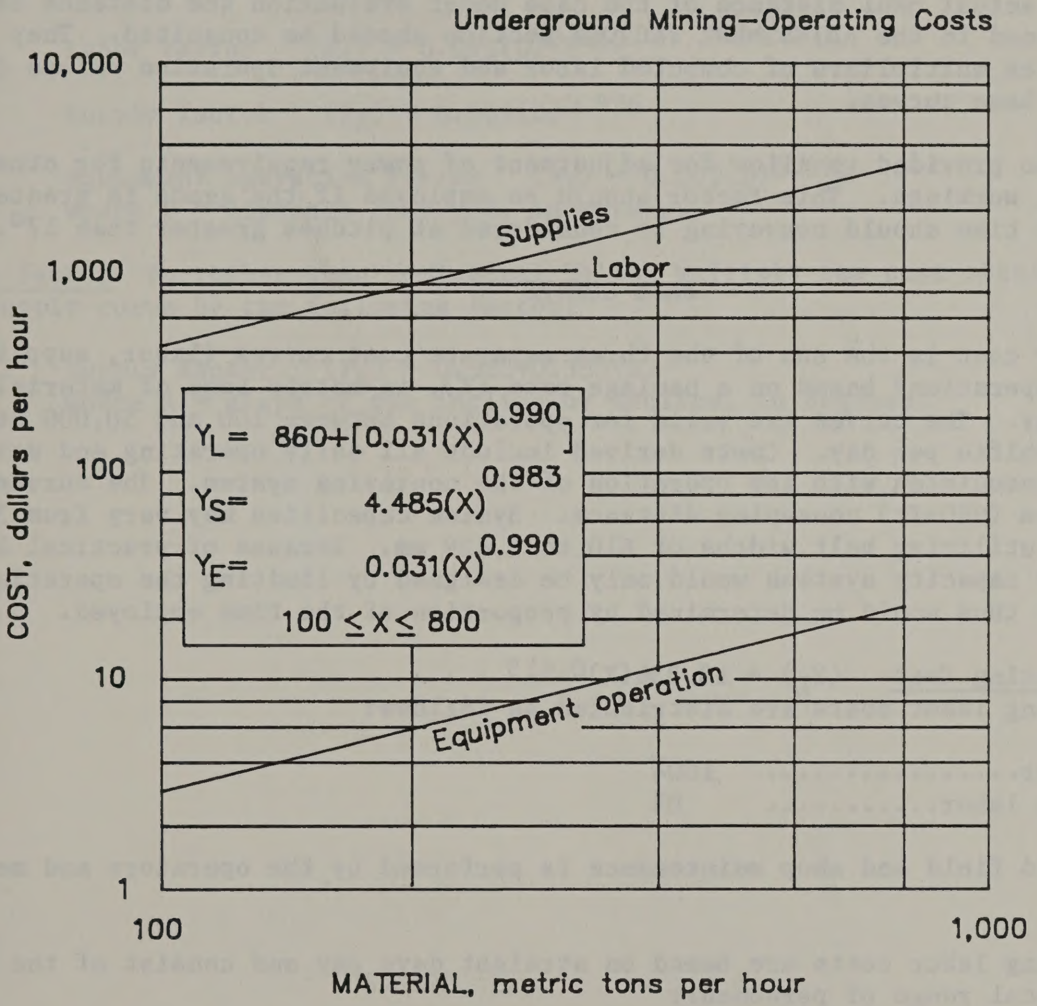
Use Factor If a hoist is used for service hoisting only, multiply the costs obtained from the supply and equipment curves by the following factors:

Supply factor $(F_S) = 0.33$

Equipment operation factor $(F_E) = 0.33$



5.2.3.1.a Hoisting
DOUBLE-DRUM



5.2.3.1.b Hoisting
FRICTION

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.5. CONVEYOR HAULAGE

Cost estimates derived through this section depict the operating cost of fixed conveyor systems underground. Typically the ore will be conveyed from an underground crusher installation to an ore pocket at a shaft station or to the surface through a portal. The base case assumes a haul distance of 300 m (980 ft) and that the conveyor system is utilized two shifts each day. As it will invariably be necessary to adjust for the actual haul distance of the case under evaluation the distance factor formulas contained in the ADJUSTMENT FACTORS section should be consulted. They should be used as multipliers of computed labor and equipment operation values derived form the base curves.

A factor is also provided to allow for adjustment of power requirements for other than horizontal workings. This factor should be employed if the grade is greater than 2%. At no time should conveying be considered at pitches greater than 17°.

BASE CURVES

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a haulage rate (X), in metric tons of material conveyed per day. The curves are valid for operations between 100 and 50,000 mt, operating two shifts per day. Costs derived include all daily operating and maintenance costs associated with the operation of the conveying system. The curves are based on a 300-m (980-ft) conveying distance. System capacities may vary from 363 to 4,460 mt/h, utilizing belt widths of 610 to 1,829 mm. Because of practical limitations, lesser capacity systems would only be designed by limiting the operating period only and thus would be determined by proportion of the time employed.

(L) Labor Operating Cost $(Y_L) = 10.036(X)^{0.415}$

The operating labor costs are distributed as follows:

Direct labor................	100%
Maintenance labor...........	0%

All required field and shop maintenance is performed by the operators and mechanics.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Belt operators..............	50%	$15.64
Belt mechanics..............	50%	15.64

Average wage for labor is $15.64 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (Y$_S$) = $0.018(X)^{0.771}$
The supply costs consist of 100% electric power for conveyor drive and facility lighting.

(E) Equipment Operating Cost (Y$_E$) = $1.010(X)^{0.535}$
The equipment operating costs consists of 100% for replacement parts and belting.

ADJUSTMENT FACTORS

Distance factor For haul distances other than the assumed 300 m (980 ft), multiply the costs obtained from the curves by the following factors:

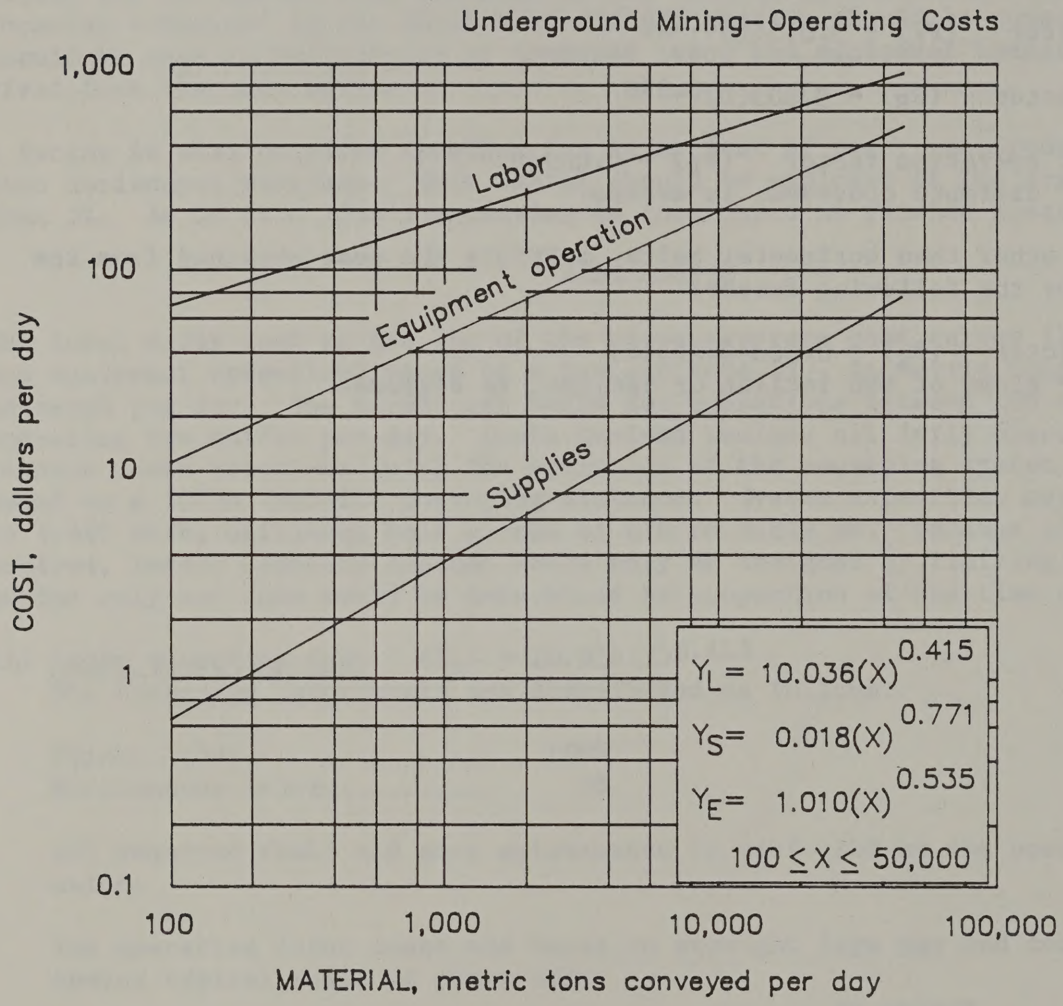
Labor factor $(F_L) = 0.095(D)^{0.413}$

Supply factor $(F_S) = 0.003(D)^{0.996}$

Equipment operation factor $(F_E) = 0.003(D)^{0.996}$
where D = distance conveyed, in meters.

Grade factor For other than horizontal belts, multiply the cost obtained from the supply curve by the following factor:

Supply factor $(F_S) = 0.983+0.355(R)$
where R = slope of the incline or decline, in degrees.



5.2.3.5. Conveyor haulage

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.7. LOAD-HAUL-DUMP HAULAGE

Through this LHD haulage curve, the cost of main haulage systems using LHD units can be determined. The base curve is designed to assess the cost of haulage in horizontal or near horizontal workings for a 500-m (1,600 ft), one-way trip distance. As it will invariably be necessary to adjust for different haul distances, factors are supplied that should be used as multipliers of the derived labor and equipment operation curve values.

The total daily cost is the sum of the two separate cost curves (labor and equipment operation) based on a haulage rate (X), in metric tons of ore and waste moved per day. The curves are valid for operations between 100 and 20,000 mt, operating two shifts per day. Costs derived include all daily operating and maintenance costs associated with the operation of the LHD units. Actual haul units used for the basis of the curve were determined by comparison of operating costs of several units with capacities ranging from 0.8-to 9.9-m^3 buckets.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 1.584(X)^{0.812}$

The operating labor costs are distributed as follows:

	Small (100 to 5,000 mtpd)	Large (5,000 to 20,000 mtpd)
Direct labor................	52%	38%
Maintenance labor...........	48%	62%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
LHD Operators...............	100%	$16.09

(E) Equipment Operating Cost $(Y_E) = 1.165(X)^{0.859}$

The equipment operating cost consists of 50% for replacement parts, 19% for fuel, 6% for lubrication, and 25% for tires.

ADJUSTMENT FACTORS

Distance factor For haul distances other than 500 m (1,600 ft) one way, multiply the costs obtained from the curves by the following factors:

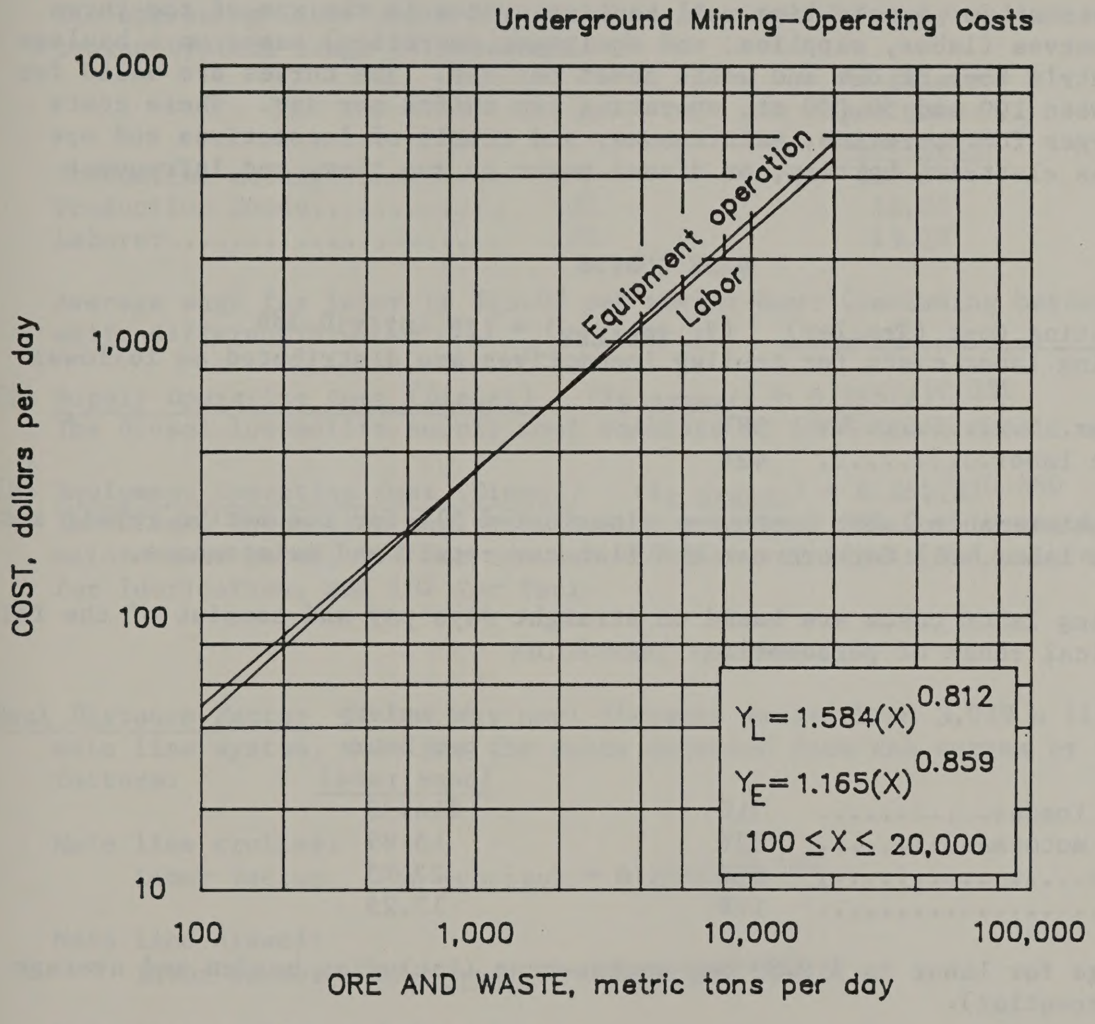
Labor factor $(F_L) = 0.426+0.00124(D)$

Equipment operation factor $(F_E) = 0.293+0.0014(D)$

where D = one way haul distance, in meters.

Grade factor A factor is also supplied for other than horizontal workings with cost related to percent grade. This factor should be used if the grade exceeds 2% and is equally applicable if dealing with inclines or declines. For other than horizontal haulageways, multiply the costs obtained from the curves by the following factors:

Grade factor $(F_G) = 0.929(1.037)^G$
where G = grade, in percent of incline or decline.



5.2.3.7. L.H.D. Haulage

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.8.1. RAIL HAULAGE
MAIN LINE

Main line haulage system costs are based on two trains, each consisting of one trolley or diesel locomotive and side-dump ore cars, operating each shift with an average one-way haul of 3,049 m with a 1% grade in favor of the loaded train.

The total daily cost for a main line rail haulage system is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a haulage rate (X), in metric tons of ore and waste moved per day. The curves are valid for operations between 100 and 50,000 mt, operating two shifts per day. These costs consist of charges for operation, maintenance, and repair of locomotives and ore cars, as well as electric, battery, or diesel power to run them, and infrequent track repair.

BASE CURVES

(L) Labor Operating Cost (Trolley) $(Y_{L\ TROLLEY}) = 128.402(X)^{0.386}$
The operating labor costs for trolley locomotives are distributed as follows:

Direct labor................	58%
Maintenance labor...........	42%

Main line maintenance labor costs are distributed 11% for locomotive repair and maintenance labor, 31% for ore car and flat car repair and maintenance.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Production loader...........	31%	$16.33
Production motorman.........	33%	15.89
Electrician.................	25%	27.73
Laborer.....................	11%	15.25

Average wage for labor is $18.82 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (Trolley) $(Y_{S\ TROLLEY}) = 0.043(X)^{0.971}$
The trolley locomotive supply cost consists of 6% track repair materials and 94% electric power.

(E) Equipment Operating Cost (Trolley) $(Y_{E\ TROLLEY}) = 7.797(X)^{0.579}$
The trolley locomotive equipment operating costs consist of 27% for locomotive repair and maintenance parts, 64% for ore car and flat car repair and maintenance parts, and 9% for lubrication.

If diesel locomotives are used instead of trolley locomotives for main line haulage, use the following equations:

(L) Labor Operating Cost (Diesel) $(Y_{L\ DIESEL}) = 104.954(X)^{0.402}$
The operating labor costs for diesel locomotive are distributed as follows:

Direct labor................	49%
Maintenance labor..........	51%

Diesel maintenance labor costs are distributed 18% for locomotive repair and maintenance labor, 33% for ore car and flat car repair and maintenance labor.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Production motorperson......	40%	\$15.89
Production loade............	43%	16.33
Laborer.....................	17%	15.25

Average wage for labor is \$15.97 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost (Diesel) $(Y_{S\ DIESEL}) = 0.385(X)^{0.331}$
The diesel locomotive supply cost consists of 100% track repair materials.

(E) Equipment Operating Cost (Diesel) $(Y_{E\ DIESEL}) = 4.382(X)^{0.680}$
The diesel locomotive equipment cost consists of 30% for locomotive repair and maintenance parts, 51% for ore car and flat car repair and maintenance parts, 9% for lubrication, and 10% for fuel.

ADJUSTMENT FACTORS

Haul Distance Factor If one-way haul distance varies from 3,049 m (10,000 ft) for a main line system, multiply the costs obtained from the curves by the following factors:

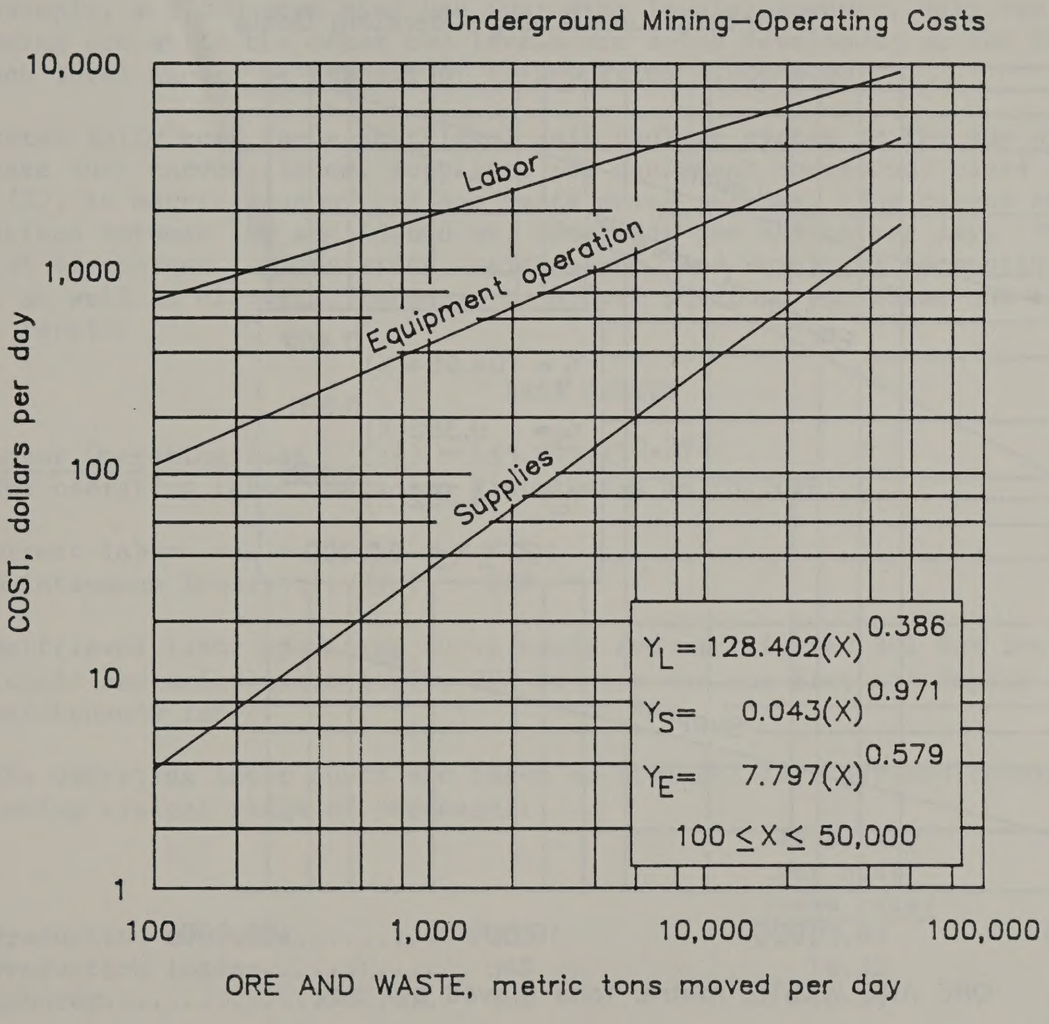
Main line trolley:
Labor factor $(Y_{L\ TROLLEY}) = 0.259(D)^{0.169}$

Main line diesel:
Labor factor $(Y_{L\ DIESEL}) = 0.171(D)^{0.221}$

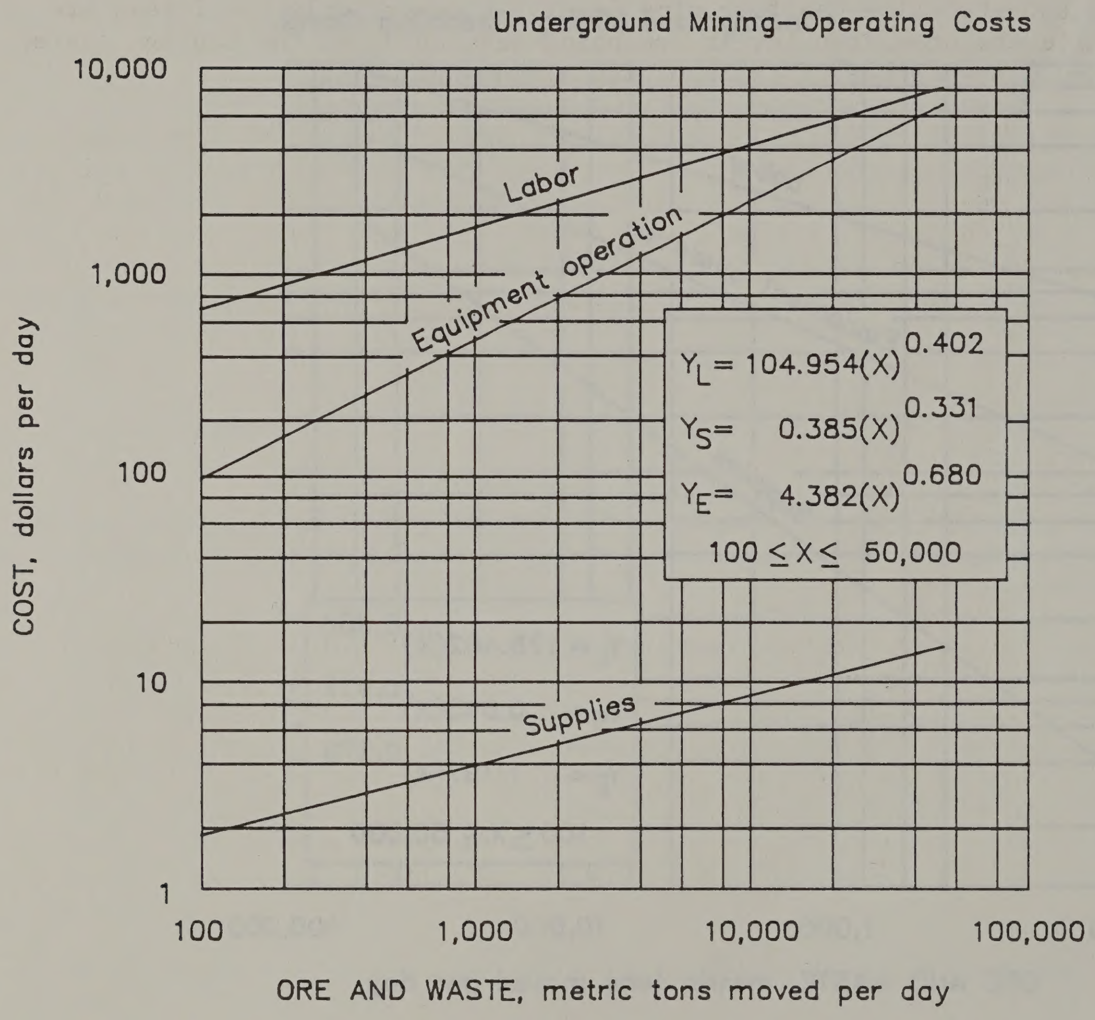
Main line trolley and diesel:
Supply factor $(Y_{S\ TROLLEY\ \&\ DIESEL}) = 0.042(D)^{0.396}$

Equipment operation factor $(Y_{E\ TROLLEY\ \&\ DIESEL}) = 0.042(D)^{0.396}$
where D = one way haul distance, in meters.

Shift Factor If a rail haulage system operates one shift per day, derive the appropriate cost by entering the cost curves at two times the system capacity, and then decrease the derived costs by 50% (i.e., a main line system operates one shift per day at 400 mtpd, use 800 mtpd, to derive curve costs, then decrease these costs by 50%). If a rail system operates three shifts per day, enter the cost curves at two-thirds the system capacity, and then increase the derived costs by 50% (i.e., a main line system operates three shifts per day at 900 mtpd, use 600 mtpd to derive the curve costs, then increase these costs by 50%).



5.2.3.8.1.a Rail haulage—main line
TROLLEY



5.2.3.8.1.b Rail haulage—main line
DIESEL

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.8.2. RAIL HAULAGE
MULTILEVEL

Multilevel haulage system costs are based on one train, comprising a battery locomotive and side-dump ore cars, operating each shift with an average one way haul distance of 915 m (3,000 ft) with a 1% grade in favor of the loaded train. The number of trains operating are determined from the daily production from each mine level. For example, a 2,000-mtpd mine has four mine levels; however, only two levels are producing ore while the other two levels are being developed; so the haulage system on each level should be capable of transporting 1,000 mtpd.

The total daily cost for a multilevel rail haulage system is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on a haulage rate (X), in metric tons of ore and waste moved per day. The curves are valid for operations between 100 and 15,000 mt, operating two shifts per day. These costs consist of charges for operation, maintenance, and repair of locomotives and ore cars, as well as electric, battery, or diesel power to run them, and infrequent track repair.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 155.792(X)^{0.290}$
The operating labor costs are distributed as follows:

Direct labor................	72%
Maintenance labor...........	28%

Multilevel labor operating curve costs are distributed 80% for locomotive repair and maintenance labor, 20% for ore car and flat car repair and maintenance labor.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Production motorman.........	33%	$15.89
Production loader...........	34%	16.33
Laborer.....................	33%	15.25

Average wage for labor is $15.83 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.105(X)^{0.564}$
The supply cost consists of 43% track repair materials and 57% electric power to recharge locomotive batteries.

(E) Equipment Operating Cost $(Y_E) = 5.062(X)^{0.558}$
The equipment operating cost consist of 28% for locomotive repair and mainten-

ance parts, 60% for ore car and flat car repair and maintenance parts, 9% for lubrication, and 3% for locomotive battery replacement.

ADJUSTMENT FACTORS

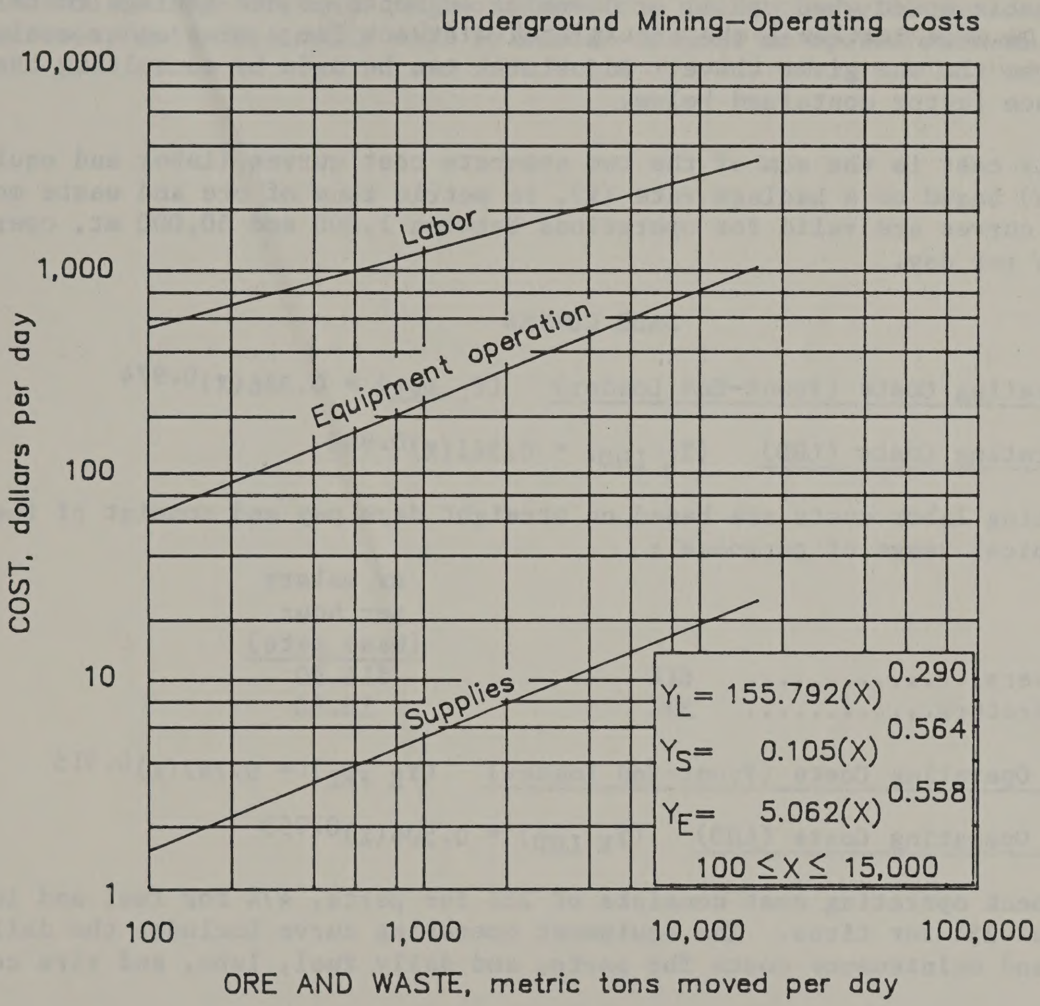
Haul Distance Factor If one-way haul distance varies from 915 m (3,000 ft) for a multilevel system, multiply the cost obtained from the curves by the following factors:

Labor factor $(Y_L) = 0.539(D)^{0.091}$

Supply factor $(Y_S) = 0.097(D)^{0.344}$

Equipment operation factor $(Y_E) = 0.097(D)^{0.344}$
where D = one way haul distance, in meters.

Shift Factor If a rail haulage system operates one shift per day, derive the appropriate cost by entering the cost curves at two times the system capacity, and then decrease the derived costs by 50% (i.e., a multilevel system operates one shift per day at 400 mtpd, use 800 mtpd, to derive curve costs, then decrease these costs by 50%). If a rail system operates three shifts per day, enter the cost curves at two-thirds the system capacity, and then increase the derived costs by 50% (i.e., a multilevel system operates three shifts per day at 900 mtpd, use 600 mtpd to derive the curve costs, then increase these costs by 50%).



5.2.3.8.2. Rail haulage—multilevel

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.3. MINE HAULAGE

5.2.3.9. TRUCK HAULAGE

The truck haulage curves cover costs of transporting ore and waste in rear-dump trucks. It is assumed that front-end loaders or LHD's are used for loading, and that one loader is required for every two trucks in use. One way haulage occurs over an average distance of 680 m (2,250 ft). The curves for truck haulage are designed to cover situations where the trucks start on a level grade, and are at a maximum attainable speed when uphill or downhill segments of the haulage route are encountered. In most instances the actual haul distance for a mine under evaluation will differ from the one given above. Adjustment can be made by consulting the haulage distance factor contained below.

The total daily cost is the sum of the two separate cost curves (labor and equipment operation) based on a haulage rate (X), in metric tons of ore and waste moved per day. The curves are valid for operations between 1,000 and 50,000 mt, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs (Front-End Loader) $(Y_{L\ FEL}) = 0.386(X)^{0.974}$

(L) Labor Operating Costs (LHD) $(Y_{L\ LHD}) = 0.361(X)^{0.980}$

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Truck drivers...............	61%	$16.90
Loader Ooerators...........	39%	16.90

(E) Equipment Operating Costs (Front-End Loader) $(Y_{E\ FEL}) = 0.747(X)^{0.915}$

(E) Equipment Operating Costs (LHD) $(Y_{E\ LHD}) = 0.506(X)^{0.953}$

The equipment operating cost consists of 28% for parts, 47% for fuel and lubrication, and 25% for tires. The equipment operating curve includes the daily overhaul and maintenance costs for parts, and daily fuel, lube, and tire costs.

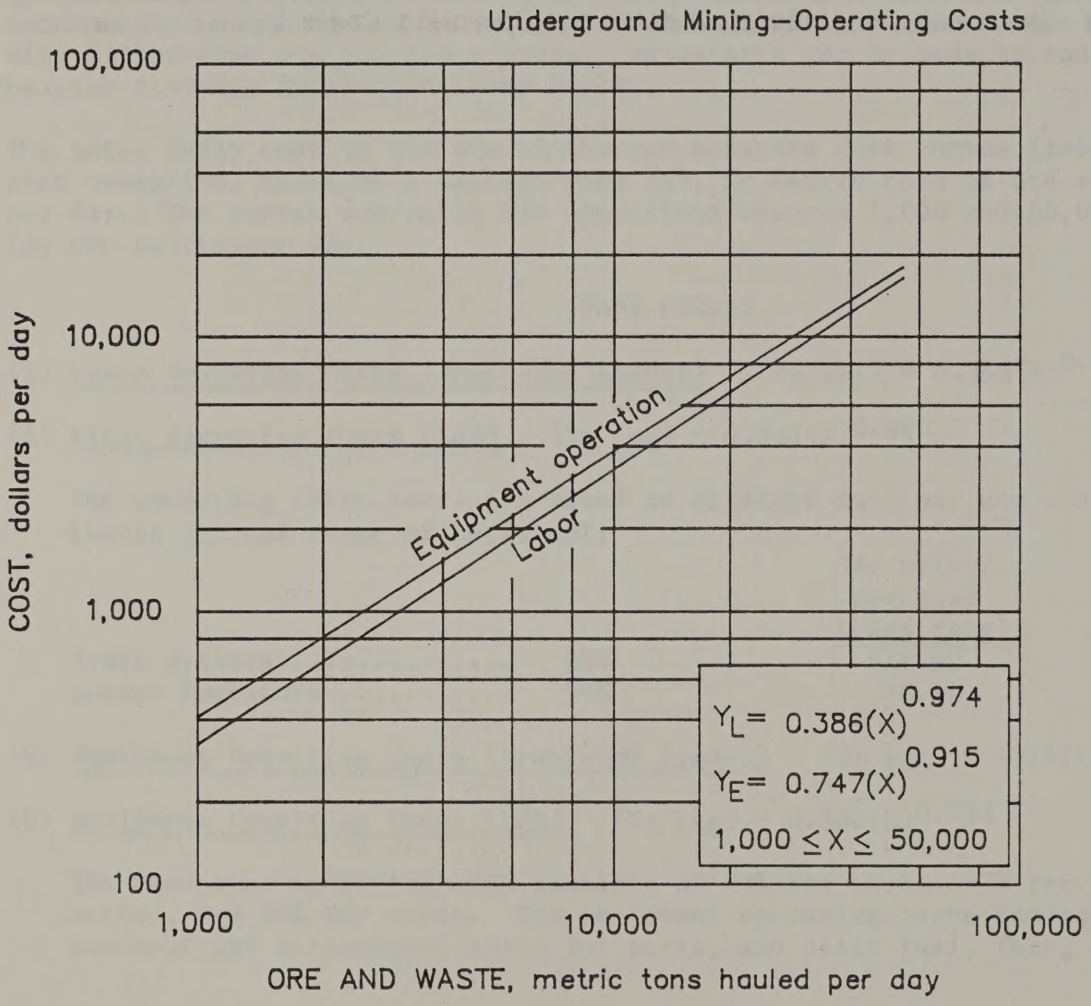
ADJUSTMENT FACTOR

Haulage Distance The given curves are valid for one-way haul distances of approximately 680 m (2,250 ft). To determine equipment and labor costs for one way-haul distances of other than 680 m (up to 3,000 ft), multiply the costs obtained from the truck haulage curves by the following factors:

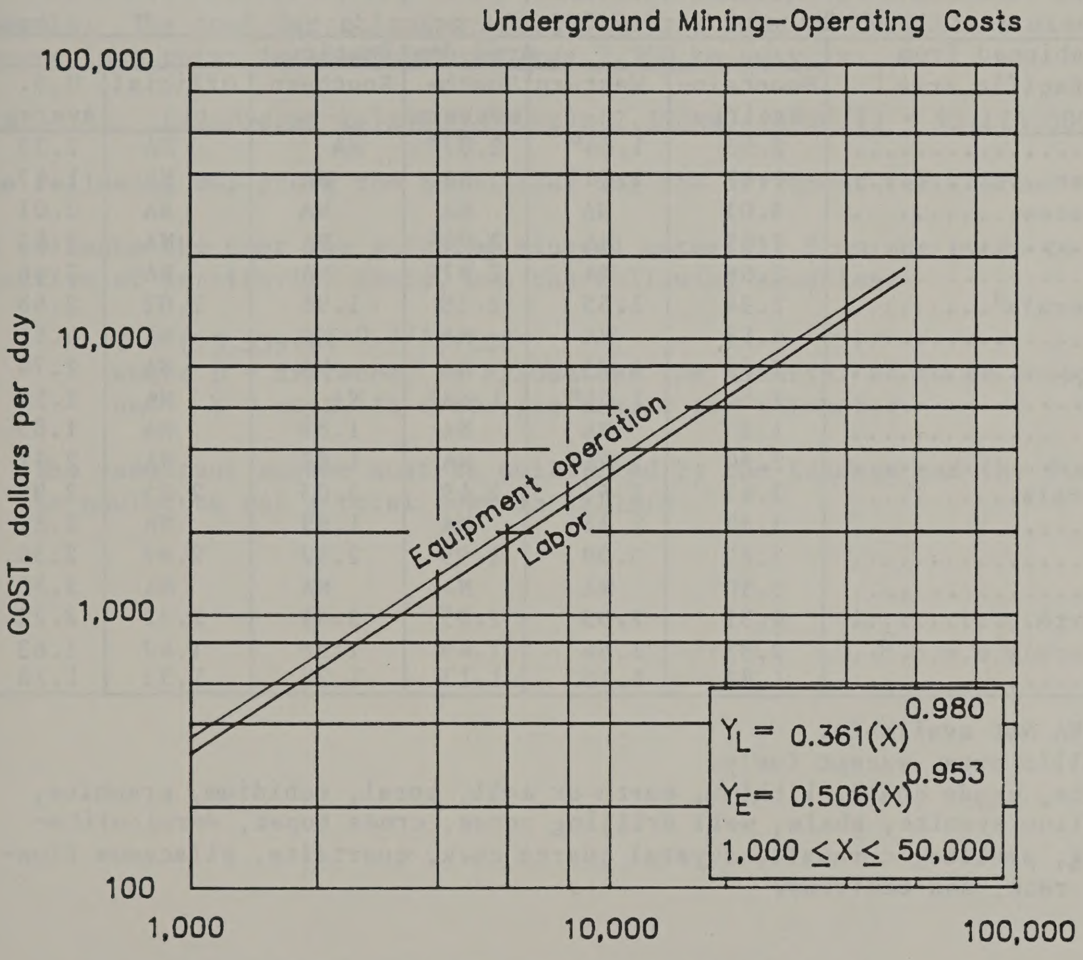
Labor factor $(F_L) = 0.055(D)^{0.445}$

Equipment operation factor $(F_E) = 0.053(D)^{0.450}$
where D = actual one way haul distance, in meters.

When the haulage distance is increased, the cycle time will show a corresponding increase, and more trucks will be needed to haul an equivalent amount of material.



5.2.3.9.a Truck haulage
FRONT–END LOADER



5.2.3.9.b Truck haulage
L.H.D.

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.4. TRANSPORTATION

5.2.4.4. LONG-DISTANCE RAIL HAULAGE

The following tabulation gives the average cost, in cents per metric ton-kilometer, for shipping mineral materials from the Mountain-Pacific territorial area (including Denver, CO) to any of the five territorial areas within the continental United States. This information is valid as of January 1984.

AVERAGE SHIPPING COSTS FOR MINERAL MATERIALS, cents per metric ton-kilometer

Material shipped from Mountain-Pacific area	Area destination					
	Mountain-Pacific	Western	South-western	Southern	Official	U.S. average
Metallic ores	2.53	1.04[e]	2.87[e]	NA	NA	2.33
Iron concentrates	1.47	1.04[e]	NA	NA	NA	1.47
Copper precipitates	3.01	NA	NA	NA	NA	3.01
Bauxite ore	2.65	NA	2.91[e]	NA	NA	2.67
Alumina calcine	2.66	NA	2.87[e]	NA	NA	2.66
Nonmetallic minerals[1]	2.94	1.55	2.18	1.96	2.02	2.68
Crushed stone	4.13	NA	NA	NA	NA	4.11
Sand or gravel	2.73	4.75	NA	NA	NA	2.74
Industrial sand	2.54	1.01[e]	1.68[e]	NA	NA	2.54
Refractories	1.83	NA	NA	1.89	NA	1.85
Clay minerals	2.94	NA	NA	1.89	NA	2.37
Fertilizer minerals	3.47	2.65	1.49	2.05	2.25	2.09
Borate, crude	3.39	2.85	NA	1.89	NA	2.67
Sulfur	3.82	3.09	1.99	2.12	2.62	2.34
Gypsum crude	3.30	NA	NA	NA	NA	3.30
Diatomaceous earth	4.31	2.03	2.05	2.31	2.32	2.22
Nonmetallic minerals n.e.c.[2]	2.35	1.84	1.49	1.58	1.47	1.63
Coal	1.87	1.25	1.13	1.30	1.33	1.26

[e] Estimated. NA Not available.

[1] Most nonmetallic ores, except fuels.

[2] Includes agate, crude chalk, lithium, earth or soil, coral, rubidium, graphite, sericite, nepheline syenite, shale, well drilling cores, crude topaz, vermiculite-unexpanded, slag, perlite, cornwall, crystal quartz rock, quartzite, silaceous fluxing ore, silica rock, and zeolites.

Source: 1983 Carload Waybill Sample data collected by Dep. of Transportation, Federal Railroad Administration, Office of Conrail.

Costs for shipping certain mineral materials from the Mountain-Pacific area to other areas may be not available (NA) for two reasons; first, shipments of these materials has dropped dramatically during the last ten years, making evaluation of costs impossible. Second, certain mineral materials are typically not shipped between two areas. For example, copper precipitates traditionally are never shipped out of the Mountain-Pacific area.

To determine the total cost of transporting a specific mineral material, first select the appropriate cost from the table listings given above, then multiply that value by the distance in kilometers the material is to be shipped, and also by the metric tonnage to be shipped. Finally, divide the answer by 100 to get a value in dollars.

Example: The cost for shipping 100,000 metric tons of fertilizer minerals from Denver to a point in the Southern Area 2,500 km away is:

$$[(2.05¢/\text{mt}\cdot\text{km})\times(100{,}000\text{mt})\times(2{,}500\text{km})/(100¢/\$) = \$5{,}125{,}000.$$

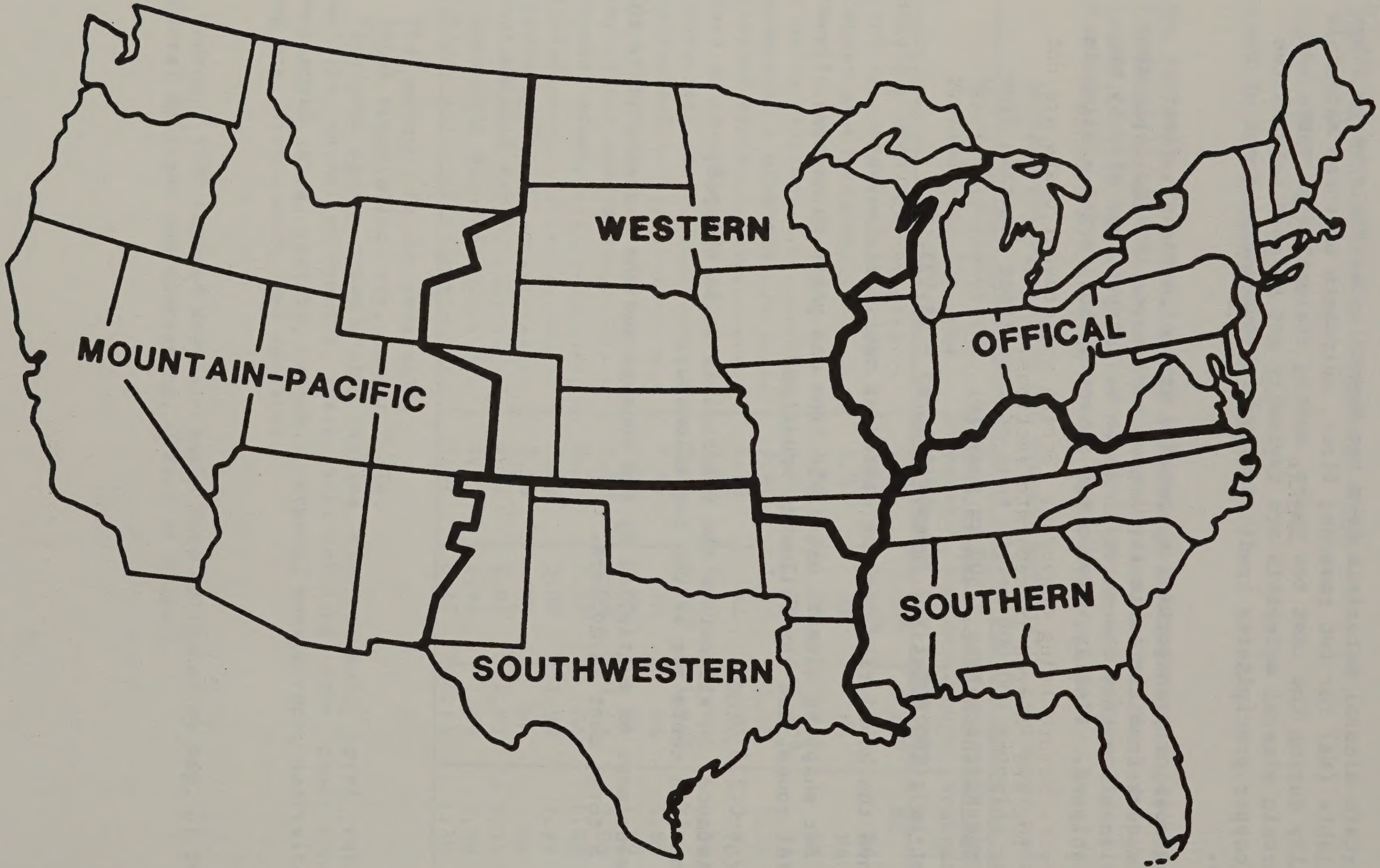
The following map shows the boundaries for the different territorial areas.

To estimate the cost for shipping mineral materials from one point to another, irrespective of territorial zones, use the following equation:

$$Y = [15.359(D)^{-0.275}]/100$$

where D = distance, in kilometers the material is to be shipped,
and Y = cost, in cents per metric ton kilometer.

The resultant answer must be multiplied by the tonnage and the distance it is to be hauled to get a total cost in dollars.


WESTERN
MOUNTAIN-PACIFIC
OFFICAL
SOUTHERN
SOUTHWESTERN

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.4. TRANSPORTATION

5.2.4.5. LONG DISTANCE SURFACE CONVEYOR

These curves cover the cost of transporting material from the mine via a single-flight conveyor belt reinforced with high-strength steel and cover a capacity range of 15,000 to 150,000 mtpd. The material is conveyed up a 10° slope for a distance of 1 km. The conveyor availability is 94%. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher costs are not included in this cost but are covered in separate sections.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons material transported per day. The curves are valid for operations between 15,000 and 150,000 mt, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the conveyor operation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 7.429(X)^{0.464}$
The operating labor costs are distributed as follows:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)
Direct labor...............	71%	47%
Maintenance labor..........	29%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)	Av salary per hour (base rate)
Operator...................	64%	54%	$16.25
Assistant operator.........	36%	46%	13.97

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.068(X)^{0.933}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.226(X)^{0.358}$
The equipment operating cost consists of 95% for repair parts and 5% for lubrication for the idlers and mechanical parts.

ADJUSTMENT FACTORS

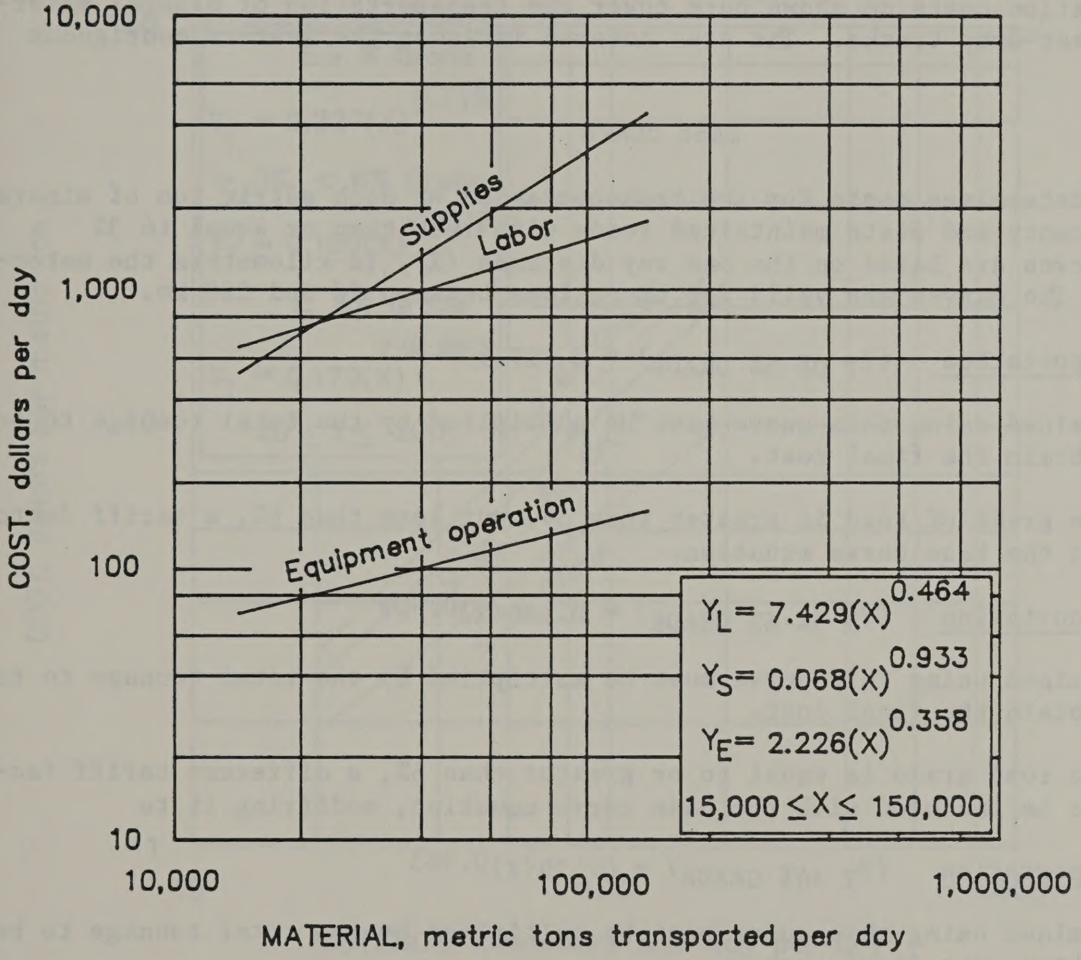
Length and Slope Factor To determine costs for varying conveyor lengths and slopes, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.815+0.190(L)$

Supply factor $(F_S) = [0.208+0.0794(S)][L]$

Equipment operation factor $(F_E) = L$
where L = length of conveyor, in kilometers,
and S = slope of conveyor, in degrees (S is between 0° and 15°).

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).



Underground Mining—Operating Costs

5.2.4.5. Long distance surface conveyor

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.4. TRANSPORTATION

5.2.4.6. LONG DISTANCE TRUCK HAULAGE

The trucking industry has undergone intensive change since its recent deregulation. Truck transportation of mineral materials has shifted predominantly away from the class rate system to the bulk commodity method. This has corresponded with a decrease in the number of carriers and an increase in competition. Each carrier now determines its own rate and tariff schedules.

Truck transportation costs as shown here cover the transportation of mineral materials by 23 mt rear-dump trucks. The area covered includes the western contiguous United States.

BASE CURVE

The base curve determines costs for the transportation of each metric ton of mineral materials via county and State maintained roads with less than or equal to 3% grades. The curves are based on the one way distance (X), in kilometers the material is hauled. The curves are valid for operations between 20 and 200 km.

(T) Truck transportation $(Y_{T\ 0\%-3\%\ \mathrm{GRADE}}) = 0.227(X)^{0.715}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average grade of road is greater than 3%, but less than 6%, a tariff factor is included with the base curve equation.

(T) Truck transportation $(Y_{T\ 3\%-6\%\ \mathrm{GRADE}}) = 0.180(X)^{0.909}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average road grade is equal to or greater than 6%, a different tariff factor will have to be included with the base curve equation, modifying it to

(T) Truck transportation $(Y_{T\ +6\%\ \mathrm{GRADE}}) = 0.179(X)^{0.963}$

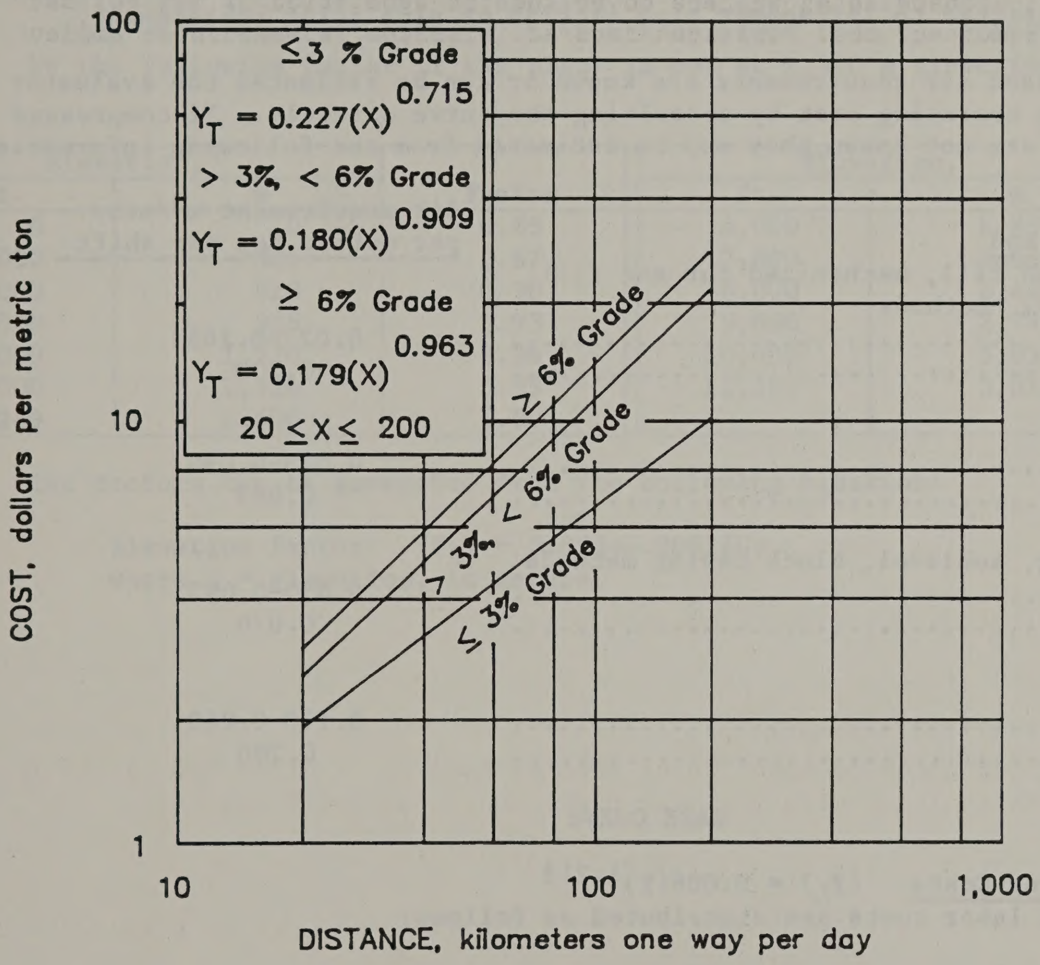
Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

ADJUSTMENT FACTORS

Long-Term Contract The final values arrived at through multiplying the tonnage by any of the three curves can be reduced by 10% to 20% if long term hauling contracts are to be used.

Tonnage If trucks with carrying capacities greater or less than 23 mt tons are used, the cost per metric should be modified accordingly.

Underground Mining—Operating Costs



5.2.4.6. Long distance truck haulage

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.2. COMPRESSED AIR FACILITIES

The total daily cost for a compressed air plant is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on mine air requirements (X), in cubic meters per minute. The curves are valid for operations between 20 and 2,000 m^3, operating two shifts per day. The costs consist primarily of charges for the maintenance and repair of compressors as well as the electric power to run them. All labor costs are restricted to repair and maintenance labor, and supplies are restricted to infrequent pipe section or pipe joint replacement.

If actual compressed air requirements are known or can be estimated the evaluator may determine the operating cost by consulting the curve directly. If compressed air requirements are not known they may be estimated from the following information:

Mining Method	Air requirement m^3/min) per metric ton per shift
Shrinkage, cut and fill, mechanized cut and fill, square-set stoping methods:	
Range..	0.027-0.265
Average......................................	0.200
Blasthole mining:	
Range..	0.073-0.094
Average......................................	0.083
Longhole drilling, sublevel, block caving methods:	
Range..	0.050-0.093
Average......................................	0.070
Open stoping:	
Range..	0.170-0.260
Average......................................	0.200

BASE CURVE

(L) Labor Operating Costs $(Y_L) = 0.006(X)^{1.213}$

The operating labor costs are distributed as follows:

Direct labor................	0%
Maintenance labor...........	100%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor..............	100%	$17.66

Average wage for maintenance labor is $17.66 per worker-hour (including burden and average shift differential)

(S) Supply Operating Costs (Y$_S$) = $0.743(X)^{1.214}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost (Y$_E$) = $0.013(X)^{1.213}$
The equipment operating cost consists of 60% for repair and maintenance parts and 40% for lubrication.

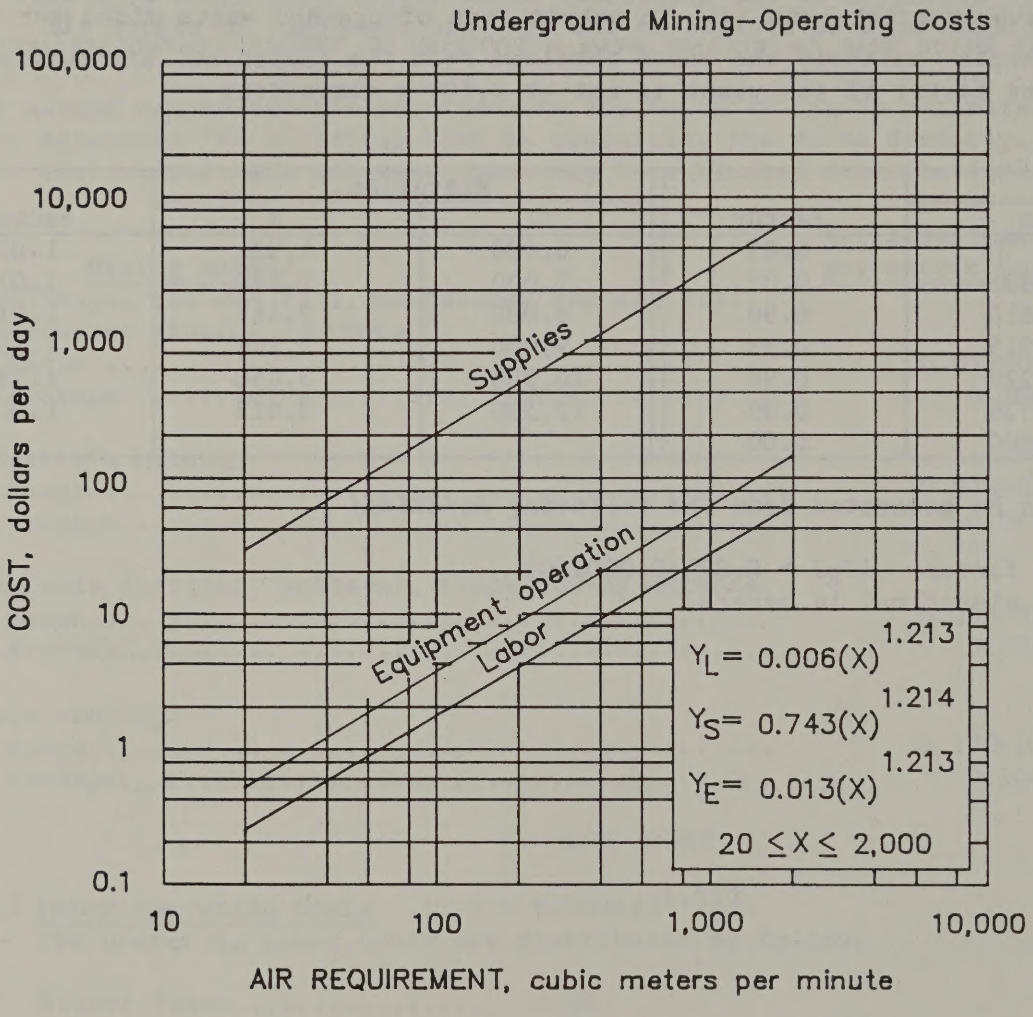
ADJUSTMENT FACTOR

Elevation Factor If elevation of the compressor plant varies from 1,600 m, a correction for altitude must be applied to the air requirements. To adjust air volume requirements, multiply the costs obtained from the compressed air curves by the following factor if the plant is not at 1,600 m elevation:

Elevation,			Elevation,		
ft	m	Factor	ft	m	Factor
0	0	0.85	6,000	1,831	1.03
1,000	305	0.87	7,000	2,136	1.07
2,000	610	0.90	8,000	2,441	1.11
3,000	915	0.93	9,000	2,746	1.15
4,000	1,220	0.96	10,000	3,050	1.19
5,000	1,526	0.99	12,500	3,813	1.31
5,249	1,600	1.00			

The factors can be generated from the following equation:

Elevation factor (F$_E$) = $0.823+0.0001(G)$
where G = elevation, in meters.



5.2.5.2. Compressed air facilities

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.5. GENERAL ITEMS--COMMUNICATIONS, SANITATION, HOUSEKEEPING, FIRE PROTECTION AND ELECTRICAL

This set of curves covers the cost of general yard work, carpentry repair, janitorial services, plumbing, road grading, ditch cleaning, general mechanical repairs, handling incoming supplies and materials, electrical maintenance and repair, and general housekeeping. The tonnage mined is based on two shifts per day.

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons of ore and waste mined per day. The curves are valid for operations between 100 and 50,000 mt, operating two shifts per day. The curves include daily operating and maintenance costs associated with utility trucks, mobile cranes, motor patrols, various cleaning materials, and electrical-plumbing supplies.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 25.640(X)^{0.577}$
The operating labor costs are distributed as follows:

Direct labor................	90%
Maintenance labor...........	10%

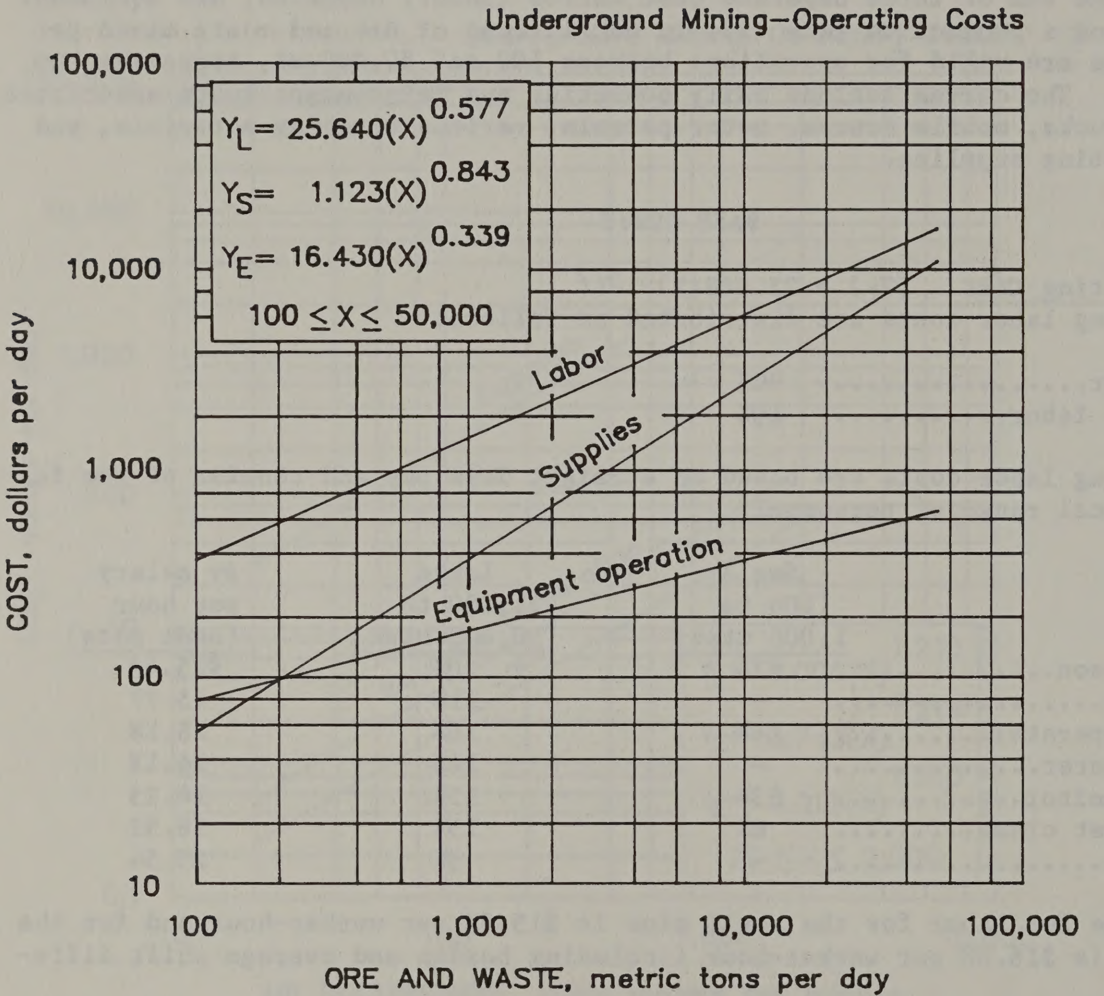
The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 1,000 mtpd)	Large (1,000 to 50,000 mtpd)	Av salary per hour (base rate)
Utility person.............	47%	20%	$15.43
Skiptender.................	-	11%	15.77
Equipment operator.........	14%	16%	18.18
General laborer............	-	14%	14.11
Security janitor...........	33%	15%	14.25
Welder, first class........	6%	15%	16.92
Electrician................	-	9%	25.54

Average wage for labor for the small mine is $15.52 per worker-hour and for the large mine is $16.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.123(X)^{0.843}$.
The supply cost consists of 100% miscellaneous supplies.

(E) Equipment Operating Cost $(Y_E) = 16.430(X)^{0.339}$.
The equipment cost consists of 37% for parts, 54% for fuel and lubrication, and 9% for tires. The equipment operating curve includes the daily overhaul and maintenance costs for parts, and daily fuel, lubrication, and tire costs.



5.2.5.5. General items
COMMUNICATIONS, SANITATIONS, HOUSEKEEPING,
FIRE PROTECTION, AND ELECTRICAL

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.7. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 4.2.5.7. when electric power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. The total cost per kilowatt hour (kW·h) replaces the commercial Denver, CO, power rate used in other sections of this manual.

These curves cover the cost of power production from a single portable power unit (see adjustment factor for multiple units) ranging from a small diesel generator with less than 100 kW output to a large gas turbine producing more than 20,000 kW of power.

Total cost is expressed in terms of cents per kilowatt hour for a specific power output. The curves cover the cost of labor for overhauls and normal repairs, parts for overhauls and normal repairs, and fuel and lubrication costs. The curves have been divided into three parts: the first part covering horizontal diesel generators from 18- to 400-kW output, the second part covering horizontal diesel generators from 400- to 2,900-kW output, and the last part covering gas turbine generators from 2,900- to 23,600-kW output.

Total cost is the sum of two separate cost curves (labor and equipment operation) based on a specific power output rating (X), in kilowatts. The curves are valid for generators between 18 to 23,600 kW. The curves include all daily operating and maintenance costs associated with power production per generator unit.

BASE CURVE

To convert from kilovolt ampere (kV·A) demand to kilowatt power output estimate the power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt output is then determined by kV·A x PF = kW. [Power Output Determination - for surface mine power output (kW), see section 2.2.4.2. For underground mine and mineral processing plant power demand (kV·A), see sections 4.2.5.3. and 6.1.8.4.(IC 9143)].

(L) Labor Operating Cost $(Y_{L\ 18\text{-}400\ kW}) = 0.169(X)^{-0.466}$
$(Y_{L\ 400\text{-}2,900\ kW}) = 0.409(X)^{-0.480}$
$(Y_{L\ 2,900\text{-}23,600\ kW}) = 0.008(X)^{-0.445}$

The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanics..................	100%	$18.11

The average wage for maintenance labor is $18.11 per worker-hour (including burden and average shift differential).

The labor curves do not contain any operating labor costs since all units operate unattended in an automatic mode (some smaller units may not have automatic starting systems and would require a manual start). The only labor necessary is that which is required for maintenance and scheduled overhauls by mechanics.

(E) Equipment Operation Costs $(Y_E \text{ 18-400 kW}) = 0.145(X)^{-0.075}$

$(Y_E \text{ 400-2,900 kW}) = 0.158(X)^{-0.070}$

$(Y_E \text{ 2,900-23,600 kW}) = 0.131(X)^{-0.122}$

The general equipment operating cost component distribution is as follows:

Discription	Repair parts	Fuel and lube	Tires
Horizontal diesel:			
18 to 400 kW.............	18.0%	73%	9%
400 to 2,900 kW..........	12.0%	79%	9%
Gas turbine: 2,900 to 23,600 kW................	11%	75%	14%

The parts category includes normal maintenance parts such as belts and pumps, and major overhaul items such as valves, injectors, brushes, and commutators. The fueling cost is based on $1.00/gal diesel fuel (at 7.093 lb/gal) or $3.20/1,000 ft^3 of natural gas with a Btu rating of 1,050 Btu's per cubic foot.

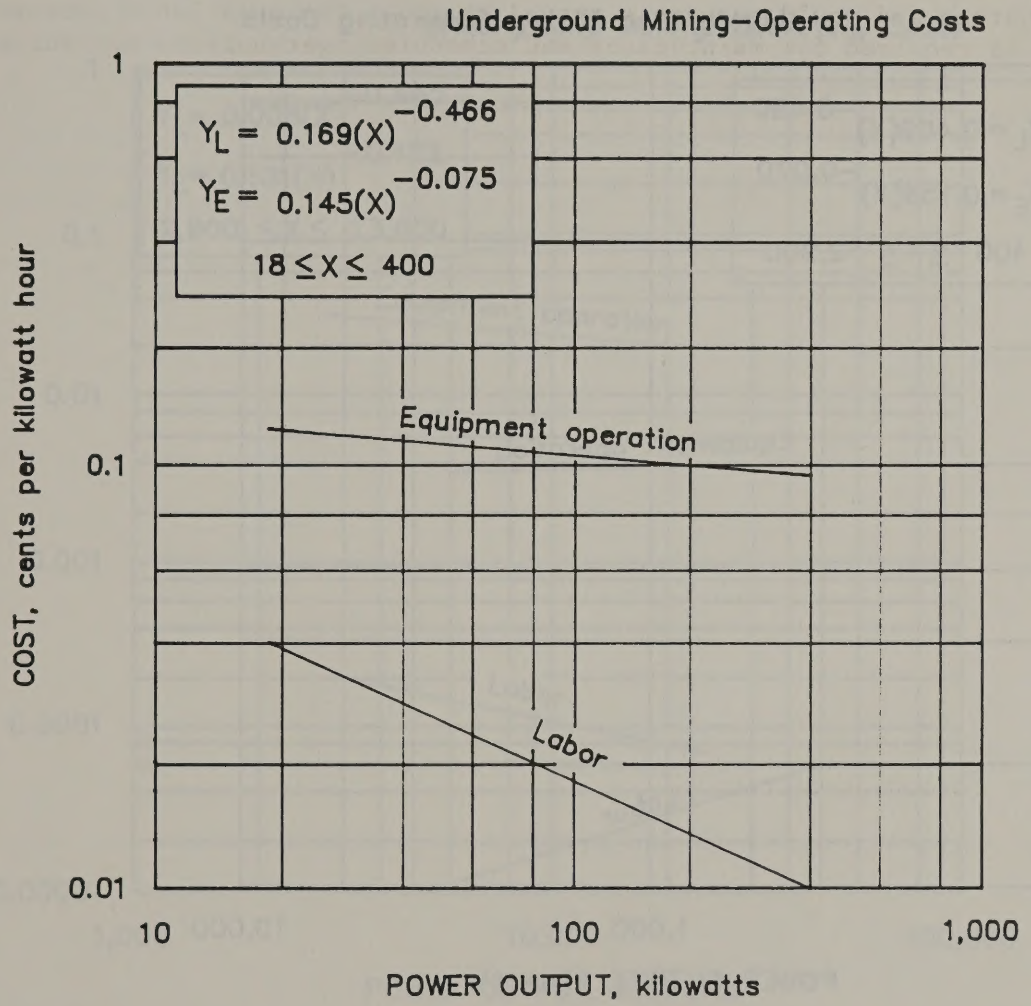
ADJUSTMENT FACTORS

Sulfur Fuels Factor If high sulfur fuels are used, multiply the labor and parts costs by the following factor:

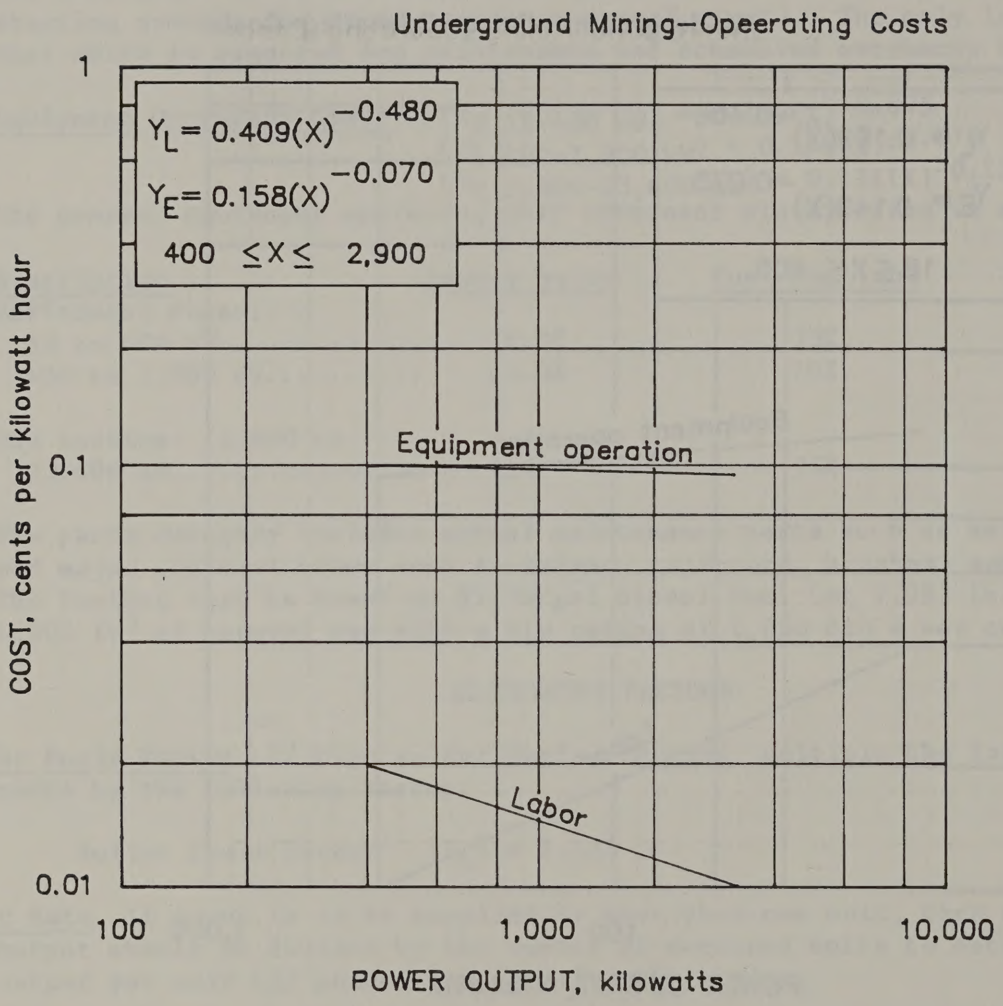
Sulfur fuels factor $(F_L) = 1.333$

Power Rate If power is to be supplied by more than one unit, then the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curves.

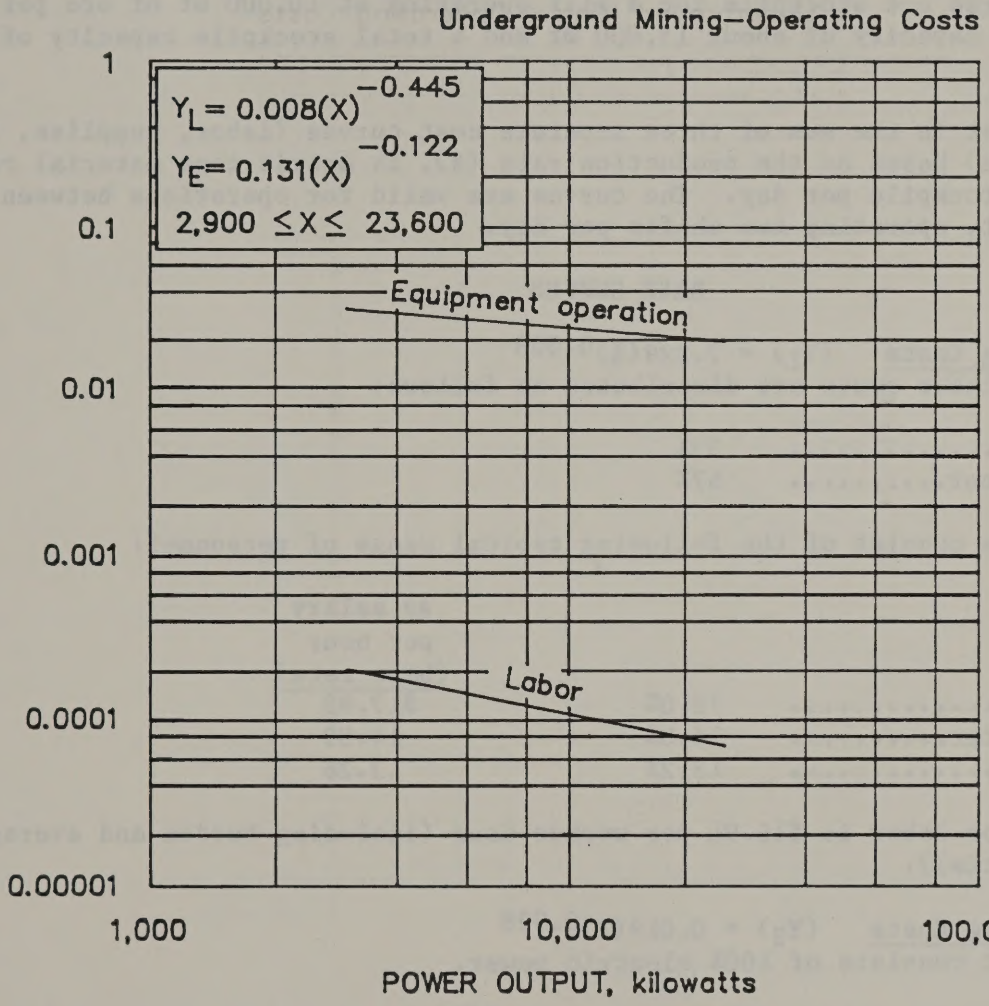
Power Source For those cases where power is supplied to the mine and mineral processing plant from different sources as a result of geographic or economic constraints, separate cost estimates, using this section, must be made to reflect the independent power outputs. This will result in different power costs for mines and mineral processing plants and must be accounted for separately in the mining and mineral processing sections of this manual.



5.2.5.7.a Portable power generation



5.2.5.7.b Portable power generation



5.2.5.7.c Portable power generation

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.9. STOCKPILE STORAGE FACILITIES

Stockpile operating costs, as determined in this section, are based on metric tons of stockpiled material reclaimed during a two-shift-per-day operation. The costs represented are only applicable for stockpiles formed and reclaimed by conveyors. The daily reclaim rate is typically about 67% of the stockpile's live storage capacity. Total stockpile capacity is normally about 600% of the daily reclaim rate. For example, a coarse ore stockpile for a mill operating at 10,000 mt of ore per day has a live storage capacity of about 15,000 mt and a total stockpile capacity of 60,000 mt.

Total operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons material reclaimed from the stockpile per day. The curves are valid for operations between 2,000 to 200,000 mt, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 7.229(X)^{0.503}$
The operating labor costs are distributed as follows:

Direct labor...............	33%
Maintenance labor..........	67%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic...................	72.0%	$17.99
Conveyor operator..........	14.8%	14.89
Laborer....................	13.2%	13.26

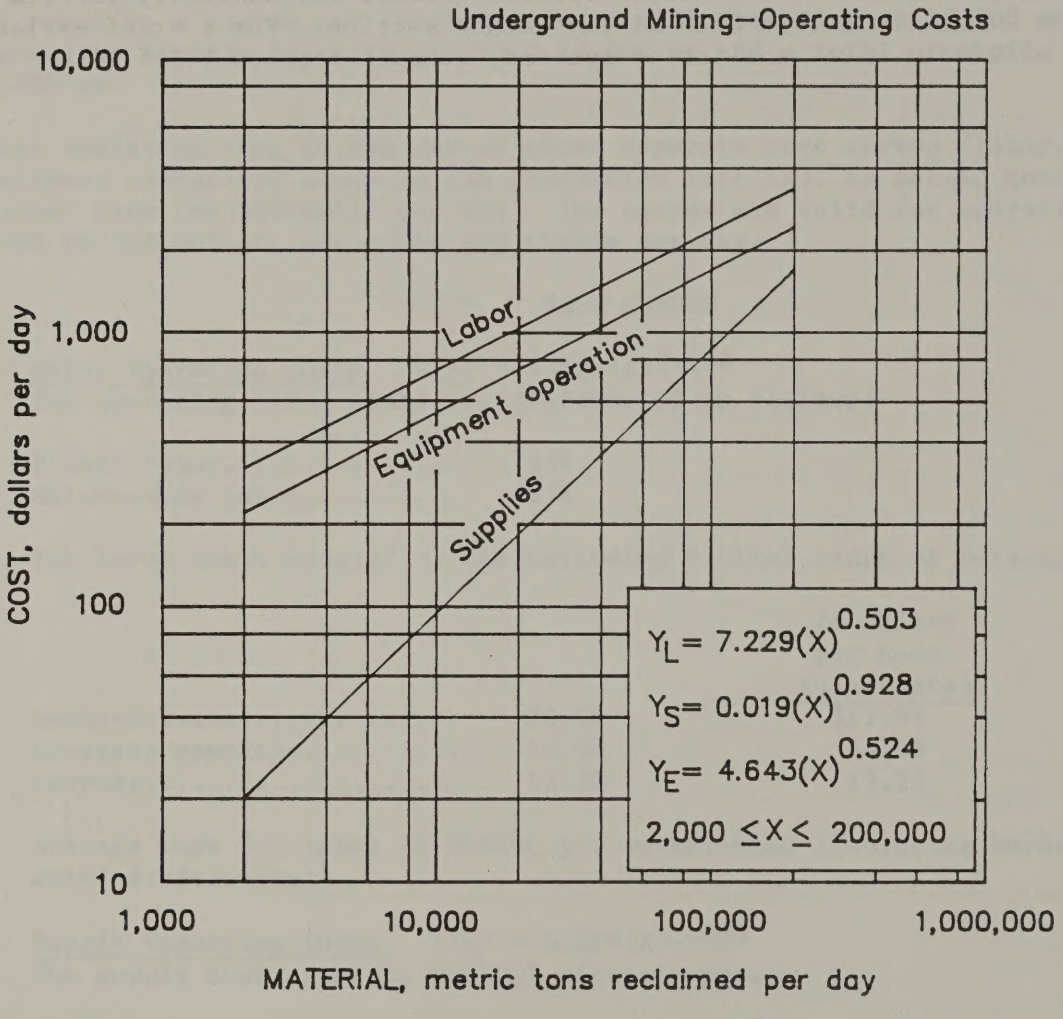
Average wage for labor is $16.91 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.019(X)^{0.928}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 4.643(X)^{0.524}$
The equipment operation curve consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTOR

Shift-Reclaim Rate If a stockpile facility is operated one shift per day, multiply the daily reclaim rate by two; calculate the operating costs from the base curves using the adjusted reclaim rate; then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operated three shifts per day, multiply the daily reclaim rate by 0.67; calculate the operating costs from the base curves using the adjusted reclaim rate; then increase the calculated cost by 50% to arrive at the adjusted cost.



5.2.5.9. Stockpile storage facilities

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.11. VENTILATION SYSTEM

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having an air capacity (X), in cubic meters per minute. The curves are valid for operations between 1,000 and 60,000 m^3, operating three shifts per day. Main ventilation system cost consists of charges for repair and maintenance of fans as well as the electric power to run them. Operating costs for auxiliary ventilation equipment is accounted for in each mining method section. For a brief explanation of factors affecting mine ventilation systems, consult section 4.2.5.11.

If mine air quantity and mine pressure head (measured in pascals), are known, consult the base curves directly. If mine air quantity and mine head are not known, requirements may be estimated using the information below.

Mining Method	Air Quantity (m^3/min) per metric ton	Mine head (Pa)
Room and pillar:		
Range..................................	0.539-5.208	1,245-2,191
Average................................	1.917	1,609
Sublevel caving, panel caving, sublevel blasthole, VCR, longhole:		
Range..................................	1.158-7.881	872-3,586
Average................................	3.394	2,111
Block caving.		
Range..................................	0.607-1.784	1,718-5,727
Average................................	1.163	2,117
Cut and fill, shrinkage, square set:		
Range	2.172-5.073	1,992-6,723
Average................................	3.789	4,171

(Pressure head conversions 1 psi = 27.7 in H_2O = 6.8948 kPa)

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 0.003(X)^{0.870}$
The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor..	100%	$17.66

Average wage for maintenance labor is $17.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.001(X)^{0.870}+[(H)(Q)(C)/1{,}997]$
The first part of the equation accounts for miscellaneous system costs and the second part of the equation accounts for electric power cost

where H = mine head in pascals
Q = quantity of air in cubic meters per minute.
and C = power cost in dollars per kilowatt hour (use $0.050/kW·h if unknown).

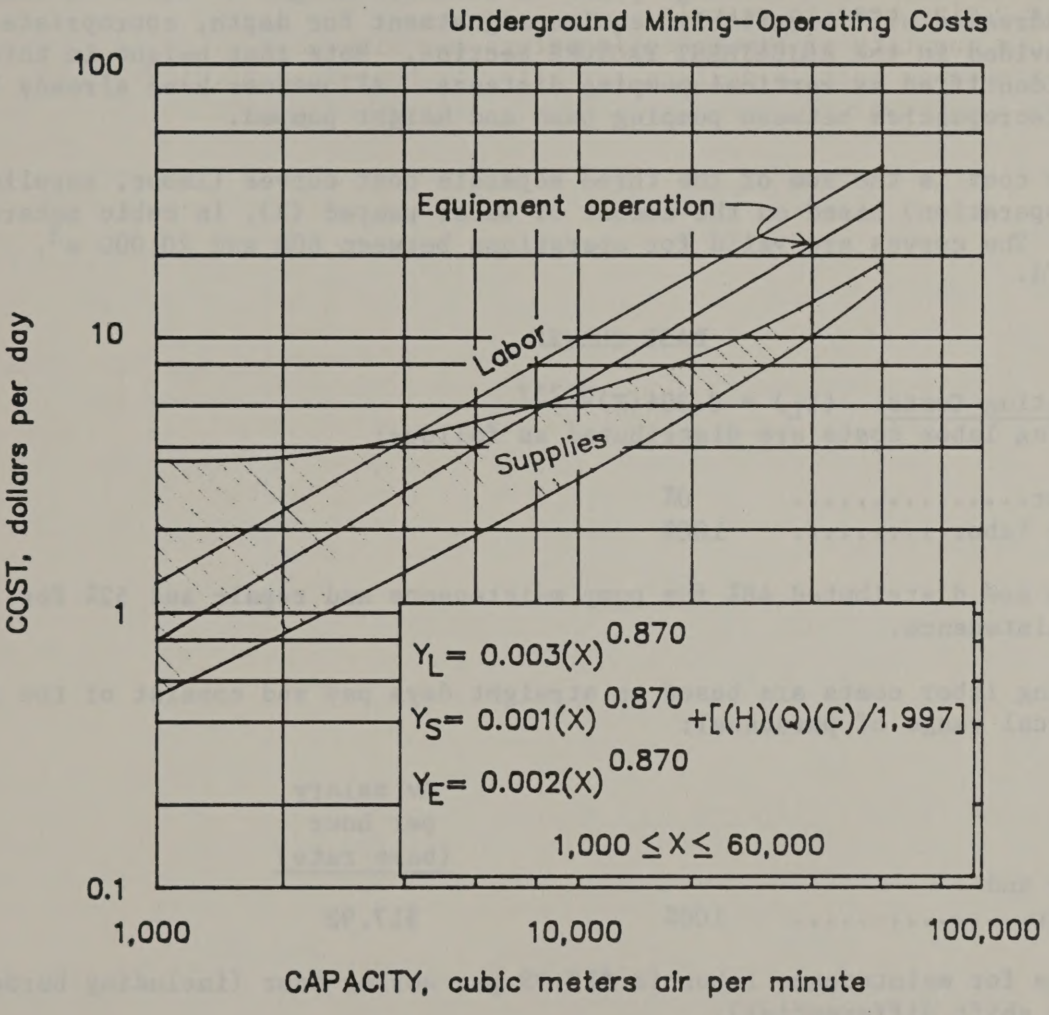
(E) Equipment Operating Cost $(Y_E) = 0.002(X)^{0.870}$
The equipment operating cost consists of 94% for fan repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Air-Warming Factor Heat-plant operating costs correlate to the number of days per year the ventilation intake air must be heated above 0° C (see section 4.2.5.11). The number of heating days per year range from 92 for a climate similar to the Denver, CO, area to 169 for a cold climate. Apply operating costs throughout the entire year. Heat-plant equipment operating costs (E) range from $56/day per 2,830 m^3/min of ventilation for a climate similar to Denver to $490/day per 2,830 m^3/min of ventilation for a cold climate. Increase labor operating costs between $6.25/day per 2,830 m^3/min of ventilation for a climate similar to Denver to $11.50/day per 2,830 m^3/min for a cold climate.

Air-Cooling Factor If an air-cooling plant is required (see section 4.2.5.11.), multiply the costs obtained from the ventilation system curves by the following factor:

Air-cooling factor $(F_{C\ COOLING}) = 1.75$



5.2.5.11. Ventilation system

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.12.1. WATER AND DRAINAGE SYSTEM
DRAINAGE AND DISPOSAL SYSTEM

The costs derived from these curves apply to underground mines where water is collected into a central drainage system and transported to sumps for initial settling and treatment. The water is then pumped, via a series of vertically emplaced stations, to either the mill or a tailings pond. A standard height of 610 m is used. As each case addressed will invariably require adjustment for depth, appropriate factors are provided in the ADJUSTMENT FACTORS section. Note that height in this discussion is identified as vertical pumping distance. Allowances have already been made for the discrepancies between pumping head and height pumped.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on the amount of water pumped (X), in cubic meters of water per day. The curves are valid for operations between 600 and 20,000 m^3, operating 24 h/d.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 0.304(X)^{0.757}$
The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

Labor costs are distributed 48% for pump maintenance and repair and 52% for pipeline maintenance.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor...............	100%	$17.98

Average wage for maintenance labor is $17.98 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.131(X)^{0.992}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 0.167(X)^{0.766}$
The equipment operating cost consists of 93% for repair and maintenance parts and 7% for lubrication.

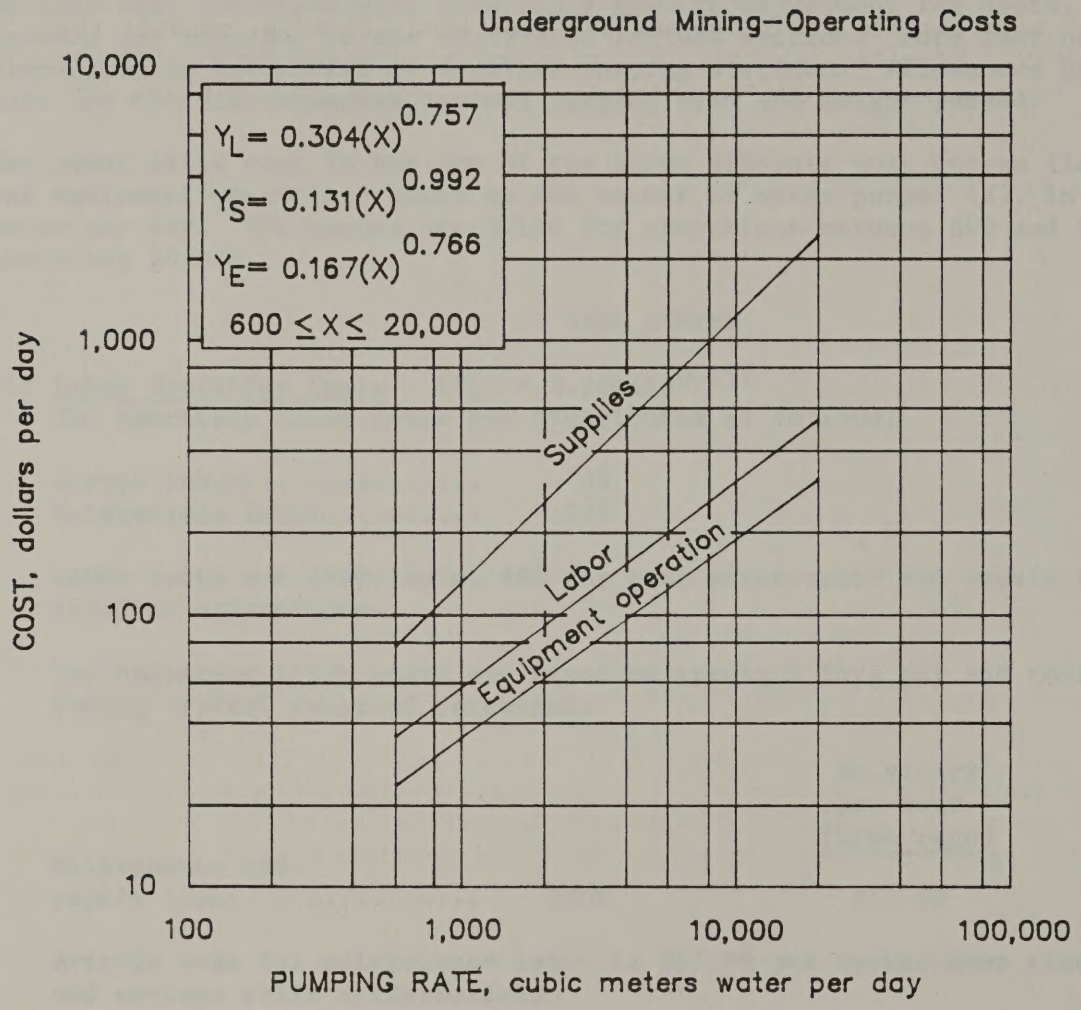
ADJUSTMENT FACTOR

Total Pumping Height If pumping height is other than the 610 m used to determine the base curves, multiply the costs obtained from the drainage and disposal curves by the following factors:

Labor factor $(H_L) = 0.731e^{[0.0005(H)]}$

Supply factor $(H_S) = 0.0019(H)^{0.977}$

Equipment factor $(H_E) = 0.572e^{[0.001(H)]}$
where H = actual pumping height, in meters.



5.2.5.12.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.12.2. WATER AND DRAINAGE SYSTEM WATER SUPPLY SYSTEM (MAKEUP WATER)

Operating costs for water systems supplying up to 125 m^3/h, typical of an underground mine or a small mine and mill complex, are calculated from this section. Operating costs for larger joint-use mine-mill systems are calculated in section 7.1.8.14 (IC 9143).

If water quantity requirements are known and are less than 125 m^3/h, consult the base curves directly. If water quantity is not known, mine requirements (Y), cubic meters water per hour, may be estimated using the equations below. Mill requirements can be estimated from section 7.1.8.14.2 (IC 9143). Water volume required for an underground mine is dependent on the principle type of drilling equipment used, the major water user in underground mines.

Air-leg drills:

Water requirement[1] $Y_{(W\ \text{AIR-LEG DRILL})} = 0.049(X_1)^{0.889}$

Jumbo and DTH drills:

Water requirement[1] $Y_{(W\ \text{JUMBO/DTH DRILL})} = 0.025(X_1)^{0.749}$

where X_1 = ore mined, in metric tons per day.

[1] Daily water quantity = m^3/h x 16 operating h/d.

Operating costs for an isolated mine (i.e., no adjacent mill) are derived directly from the base curves. For a joint-use system, combine mine and mill water requirements and derive the total operating costs from the appropriate curve.

BASE CURVES

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having mine water requirements (X), in cubic meters per day. The curves are valid for operations between 40 and 2,000 m^3, operating two shifts per day. These costs consist of charges for the maintenance and repair of pumps as well as the electric power to run them and infrequent pipeline repair.

(L) Labor Operating Cost $(Y_L) = 2.058(X)^{0.444}$

The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

Labor operating curve component costs are distributed 32% for pump repair and maintenance and 68% for pipeline repair and maintenance.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor.............	100%	$17.98

Average wage for maintenance labor is $17.98 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.680(X)^{0.627}$
The supply cost consists of 51% pipeline repair parts and 49% electric power.

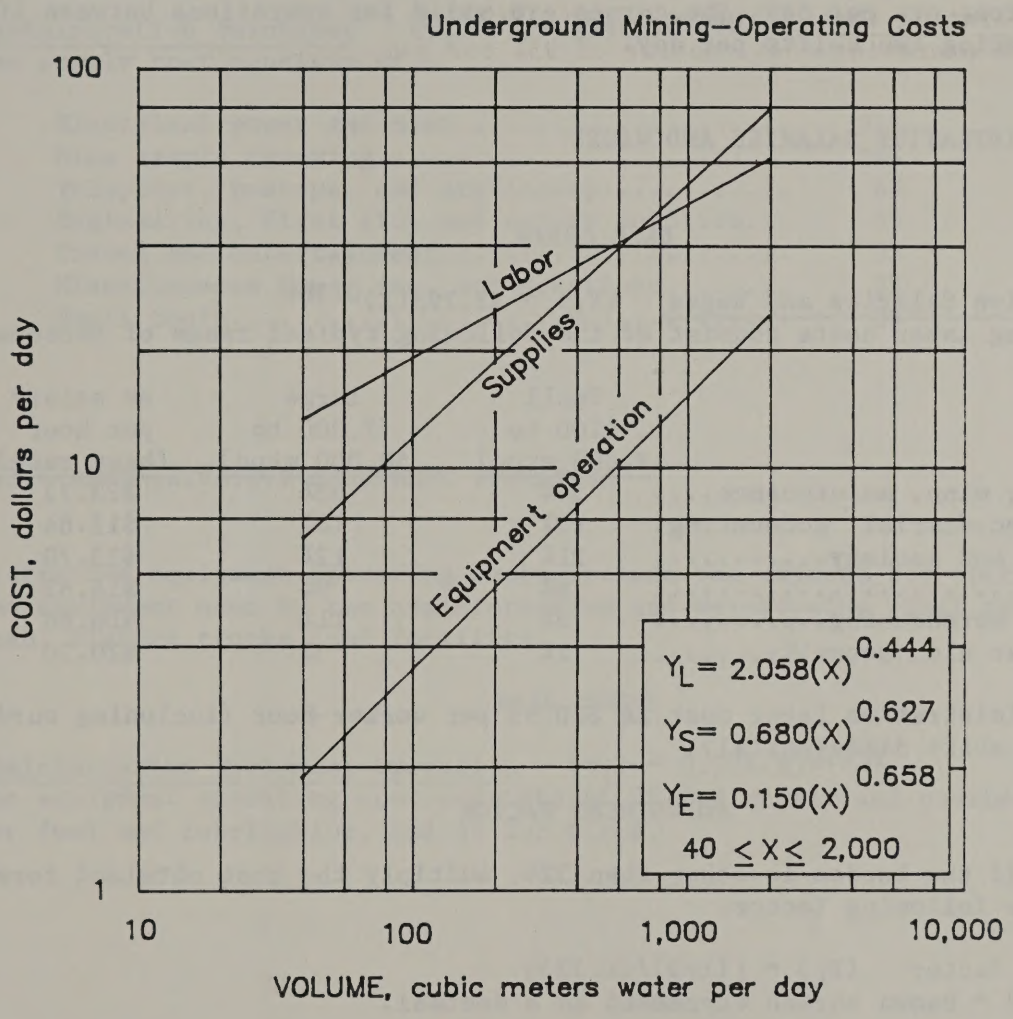
(E) Equipment Operating Cost $(Y_E) = 0.150(X)^{0.658}$
The equipment operating cost consist of 95% for pump repair and maintenance parts and 5% for lubrication.

ADJUSTMENT FACTORS

Joint-Use After deriving the joint-use water system operating cost from the appropriate curve using the combined mine and mill water quantity requirements, allocate mine operating cost versus mill operating cost based on the percentage of water quantity demand (i.e., if the mine requires 10% of the total quantity, operating cost is split 10% mine and 90% mill).

Purchased Water Factor On occasion, purchase of water from a nearby municipal water system is a viable alternative for a mine. If this is either the present case or is being evaluated as a possible water source, the water purveyor charges would be the sole operating cost. The evaluator should contact the local supplier to determine what the actual charges would be.

Shift Factor Curve costs should be reduced 50% for a one-shift-per-day operation and increased 50% for a mine operating three shifts per day.



5.2.5.12.2. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)

5.2.6. GENERAL EXPENSE
ADMINISTRATIVE COSTS

The general expense curve for underground mining administrative salaries and wages is intended to cover the supervision and various other administrative functions required for underground mines of varying sizes. The number of administrative employees varies from 3 to 4 persons at a smaller mine (100-300 mtpd) to as many as 40 or more in large mines (7,000 mtpd and up). The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons ore per day. The curves are valid for operations between 100 to 50,000 mt, operating two shifts per day.

5.2.6.1. ADMINISTRATIVE SALARIES AND WAGES

BASE CURVE

(L) Administrative Salaries and Wages $(Y_L) = 33.293(X)^{0.586}$
The operating labor costs consist of the following typical range of personnel:

	Small (100 to 7,000 mtpd)	Large (7,000 to 50,000 mtpd)	Av salary per hour (base rate)
Supervision; mine, maintenance....	54%	55%	$23.72
Clerical; secretarial, accounting.	13%	10%	$12.84
Engineering and geology...........	21%	12%	$23.70
Assaying..........................	8%	9%	$16.62
Purchasing, warehousing...........	2%	11%	$16.66
Safety, first aid, security.......	2%	3%	$20.70

Average administrative labor cost is $20.95 per worker-hour (including burden and average shift differential).

ADJUSTMENT FACTOR

Burden Factor If the burden is other than 32%, multiply the cost obtained form the curve by the following factor:

Burden factor $(F_L) = [(1+B)/(1.32)]$
where B = known burden expressed as a decimal.

5.2.6.2. ADMINISTRATIVE PURCHASES

Daily operating costs for administrative supplies include the mine's portion of electric power and heating bill for office, assay laboratory, repair shops, and warehouses; supplies for assaying mine samples; and telephone, postage, and stationary costs. Costs also included are engineering, first aid, and safety supplies; travel and entertainment expenses; miscellaneous fees, dues, and donations; and small tool replacement costs.

BASE CURVE

(S) Administrative Purchases $(Y_S) = 33.238(X)^{0.380}$
The supply cost consists of

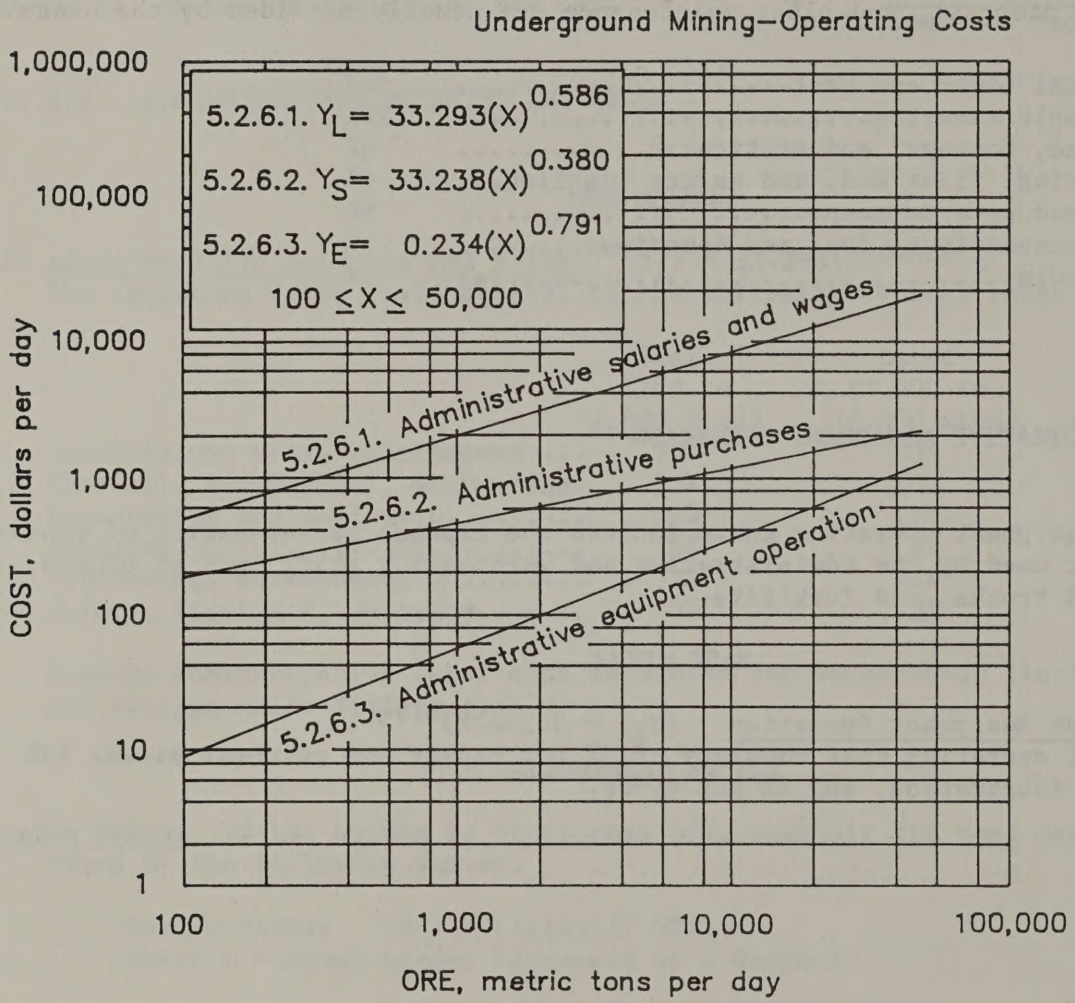
Electrical power and heat....................	51%
Mine sample assaying.........................	24%
Telephone, postage, and stationary...........	6%
Engineering, first aid, and safety supplies...	5%
Travel and entertainment.....................	9%
Miscellaneous fees, due, and donations........	2%
Small tools..................................	3%

5.2.6.3. ADMINISTRATIVE EQUIPMENT OPERATION

Administrative equipment operating costs include the expense for operation of vehicles and equipment used by the administrative and warehousing staff such as pickup, crew cab, flatbed trucks, and forklifts.

BASE CURVE

(E) Administrative Equipment Operation $(Y_E) = 0.234(X)^{0.791}$
The equipment operating cost consists of 3% for repair and overhaul parts, 93% for fuel and lubrication, and 4% for tires.



5.2.6.1.—3. General expenses
ADMINISTRATIVE SALARIES AND WAGES
ADMINISTRATIVE PURCHASES
ADMINISTRATIVE EQUIPMENT OPERATION

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.7. INFRASTRUCTURE

5.2.7.3. TOWNSITE-CAMPSITE

CAMPSITE

Where conditions such as remote location or seasonal operation require a single status-campsite (i.e., room, board, and recreation facility), the daily operating cost should be derived from the following base cost curve. Today a caterer is usually employed to provide board, housekeeping, and recreation supervision. Heat, lights, garbage disposal, and plant maintenance are usually provided by the owner.

BASE CURVE

The total daily cost is derived from the supply curve based on the total number of persons who occupy the campsite (X). The curve is valid for campsites occupied by 20 to 1,000 persons. All persons receive both room and board.

(S) Supply Operating Cost $(Y_S) = 37.143(X)^{0.897}$

	Small (20 to 450 persons)	Large (450 to 1,000 persons)
Board......................	61.5%	59.0%
Housekeeping and recreation.	23.9%	23.0%
Heat.......................	6.4%	9.0%
Light......................	2.4%	3.4%
Maintenance................	5.8%	5.6%

If the number of persons requiring board varies from the number of persons requiring room, use the following equation:

(S) Supply Operating Cost $(Y_S) = [37.143(X)^{0.897}][0.60(B/R)+0.40(R)]$
where B = number of persons requiring board only,
and R = number of persons requiring room only.

These curves are based on a caterer who provides all necessary personnel for food service, housekeeping, distribution and collection of mail, monitoring recreation, etc., and all necessary supplies, such as pots, pans, dishes, silverware, sheets, pillowcases, blankets, waste cans, recreation supplies, janitorial supplies, food, etc. The evaluator must add the cost for local, State, or Federal taxes where required.

ADJUSTMENT FACTORS

Owner-Operator Factor When the facility is owner-operated rather than catered, multiply the cost obtained from the curve by the following factor:

Owner-operator factor $(F_O) = 0.93$

Diesel Power Factor When the electric power is provided by a diesel-electric system rather than a power line grid, multiply the cost obtained from the curve by the following factor:

Diesel power factor $(F_D) = 1.04$

TRAILER COURT

Where conditions such as remote location or lack of available housing require installation of a family trailer court complete with utilities, laundromat, recreation facilities, blacktop driveway, and possibly swimming pool, the daily operating cost should be derived from the following two curves. The total daily cost is derived from the supply curve, based on the total number of trailer spaces, (X), required. The curve is valid for trailer courts with 20 to 1,000 units.

BASE CURVE

The curves are based on trailer and facility maintenance, insurance, casualty insurance, supervisory and worker wages, plus overhead, heat, and lights.

(S) Supply Operating Cost $(Y_{S\ FREE}) = 49.514(X)^{0.590}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are free to supervisors and workers. The company pays all operating costs on the facility.

(S) Supply Operating Cost $(Y_{S\ RENTED}) = 1{,}676.049(X)^{-0.716}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are rented to supervisors and workers. The company pays for any loss on the facility.

ADJUSTMENT FACTORS

Swimming Pool Factor When the trailer court does not provide a swimming pool, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Swimming pool factor $(F_{P\ FREE}) = 0.82$

When the spaces and trailers are rented and the trailer court has 52 or more units it will show a profit. If there are less than 52 units, multiply the curve $(Y_{S\ RENTED})$ by the following factor:

Swimming pool factor $(F_{P\ RENTED}) = 0.05$

Trailer Space Rental Factor When the occupants rent trailer space for their own trailers, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Trailer space rental factor $(F_{R\ FREE}) = 0.36$

PERMANENT HOUSING

Company totally owned and operated townsites are decreasing in number because of their high cost and persistent social problems. The trend seem to be toward small family housing facilities combined with an existing nearby city.

Large townsite permanent housing:

Today, the military appears to be the greatest user of this type of facility. The Air Force provides housing to its officers and enlisted personnel. The Government pays for housing and facility maintenance, all utilities, supervisor, and worker labor, etc. The average operating costs for 1983 were:

McCord Air Base - 993 units: $6.66 per day per unit.
Fairchild Air Base - 1,580 units: $6.93 per day per unit.

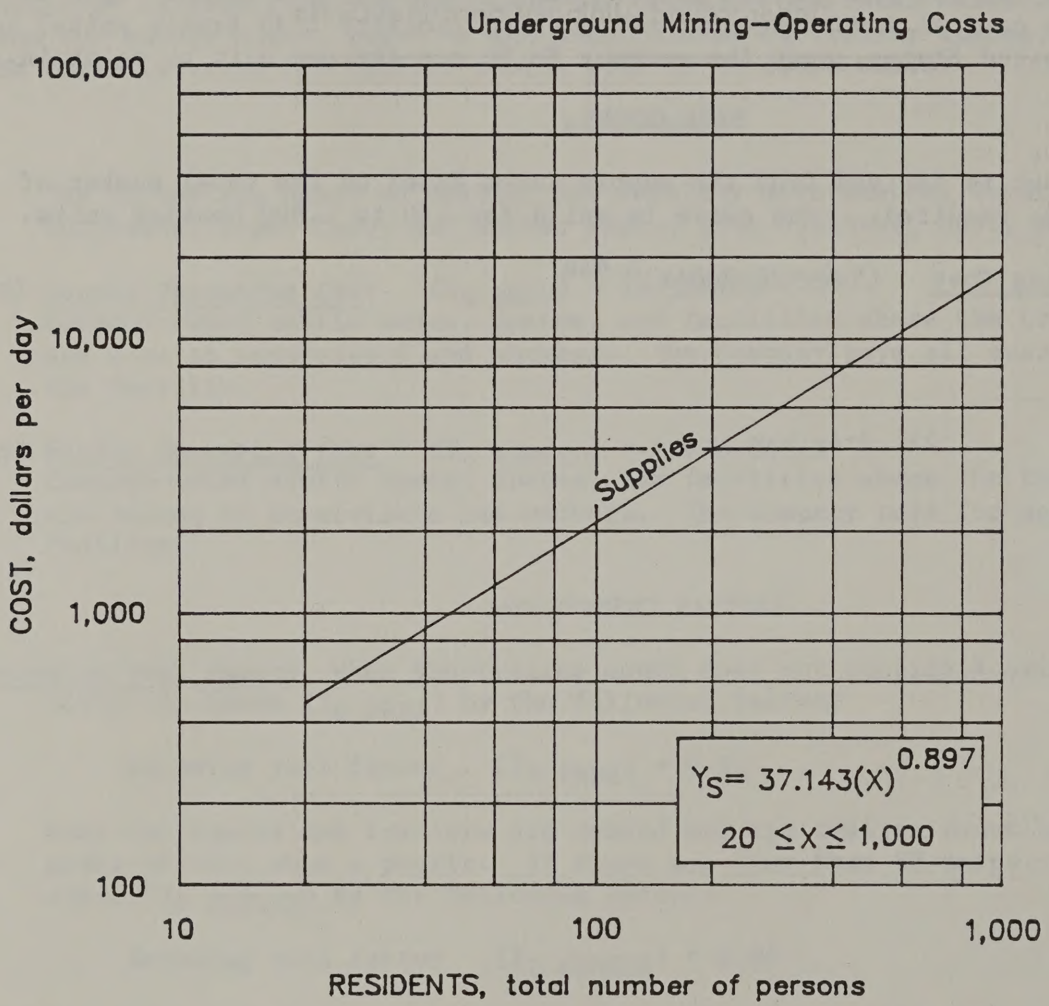
Small townsite permanent housing

These facilities are generally rented to their occupants at a modest fee with the company paying for the general maintenance, insurance, and taxes. Rent is applied to the capital investment. A new housing facility (175 family units) in the western United States, cost the company $0.98 per day per unit to maintain.

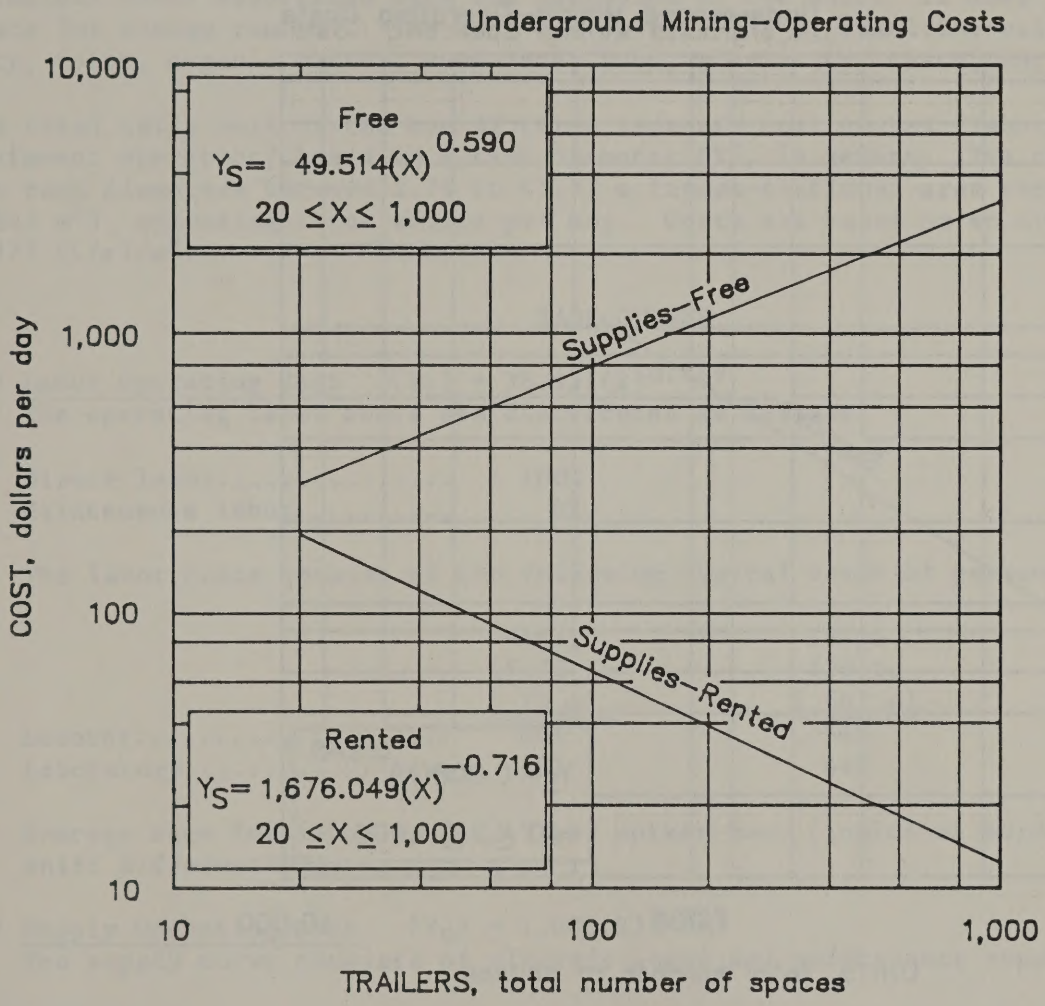
BASE CURVE

The total daily cost is derived from the supply curve based on the total number of housing units, (X), required. The curve is valid for 140 to 1,900 housing units.

(S) Supply Operating Cost $(Y_S) = 0.008(X)^{0.948}$

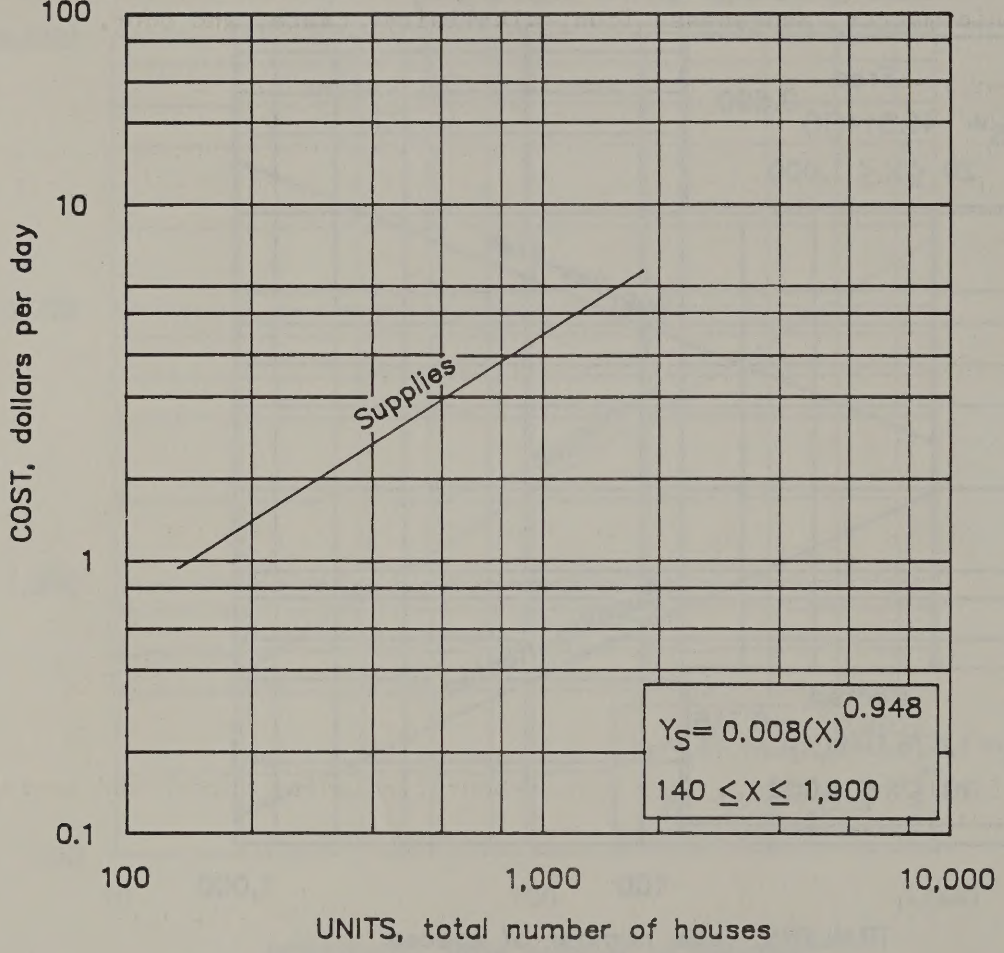


5.2.7.3.a Townsite-Campsite
CAMPSITE



5.2.7.3.b Townsite–Campsite
TRAILER COURT

Underground Mining—Operating Costs



5.2.7.3.c Townsite–Campsite
PERMANENT HOUSING

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.7. INFRASTRUCTURE

5.2.7.4.1. WASTEWATER TREATMENT CLARIFICATION

This operation is a solids-contact clarifier used for water clarification by precipitation and/or coagulation. This cost curve is intended to remove suspended solids formed after final neutralization of out-of-pipe effluent. The curves include all principal costs associated with the operation of the unit. It does not include costs for sludge removal. The unit can selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, alkalinity, taste, and odor.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a tank diameter (X), in meters. The curves are valid for tank diameters between 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2), operating three shifts per day. Costs are based on an overflow rate of 0.377 $(L/s)/m^2$.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 38.931(X)^{0.119}$
The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

	Small (5.72 to 75 m)	Large (75 to 1,661 m)	Av salary per hour (base rate)
Laborer....................	60%	54%	$13.66
Laboratory.................	40%	46%	15.89

Average wage for labor is $14.43 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.083(X)^{0.633}$
The supply curve consists of electric power and maintenance supplies.

	Small (5.72 to 75 m)	Large (75 to 1,661 m)
Electric...................	60%	34%
Maintenance................	40%	66%

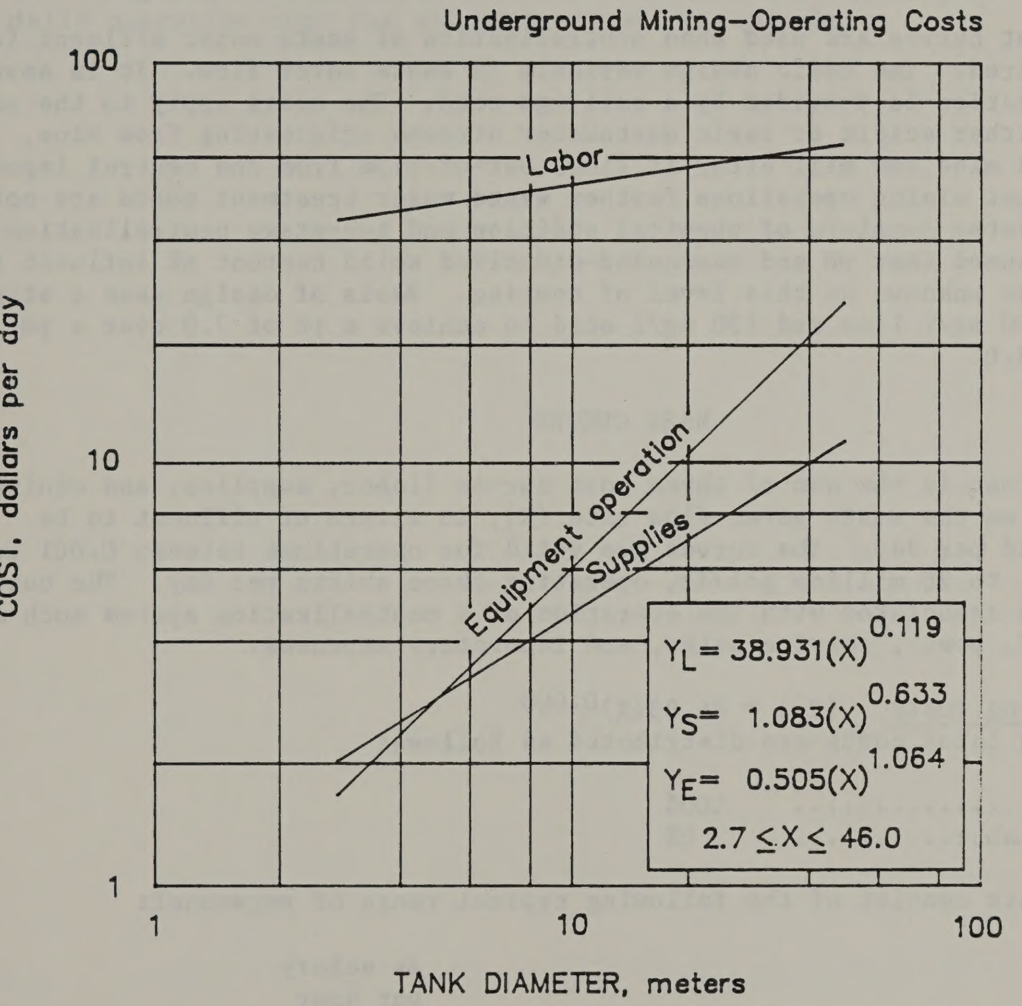
(E) Equipment Operating Cost $(Y_E) = 0.505(X)^{1.064}$
The equipment operation curve consists of 100% for repair parts and covers the daily operation cost for all clarification equipment.

ADJUSTMENT FACTOR

Flocculant Factor Normally, additional flocculants are not needed in the mine waste water treatment after neutralization. However, if polymers are needed or used, add the following factor to the supply cost obtained from the curve:

Supply factor $(F_S) = 0.334(D)^{1.812}$
where D = clarifier tank diameter, in meters.

The polymer is based on a standard dosage of 1.5 mg/L influent and an average polymer cost of 2.10/lb.



5.2.7.4.1. Wastewater treatment
CLARIFICATION

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.7. INFRASTRUCTURE

5.2.7.4.2. WASTEWATER TREATMENT NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The operating cost curves are used when neutralization of waste water effluent (out-of-pipe) is required. The basic design variable is waste water flow. It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic wastewater streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) based on the waste water flow rate (X), in liters of effluent to be treated per second per day. The curves are valid for operations between 0.001 to 876 L/s (22.8 gal to 20 million gal/d), operating three shifts per day. The curves include all costs associated with the operation of a neutralization system such as labor, lime, acid, power, service water, and laboratory expenses.

(L) Labor Operating Costs $(Y_L) = 84.85(X)^{0.000}$
The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Laborer....................	89%	$15.80
Laboratory.................	11%	15.80

The average labor cost is $15.80 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 24.13(X)^{0.950}$
$(Y_{S\ 8.76\text{-}876\ L/s}) = 21.282(X)^{0.997}$

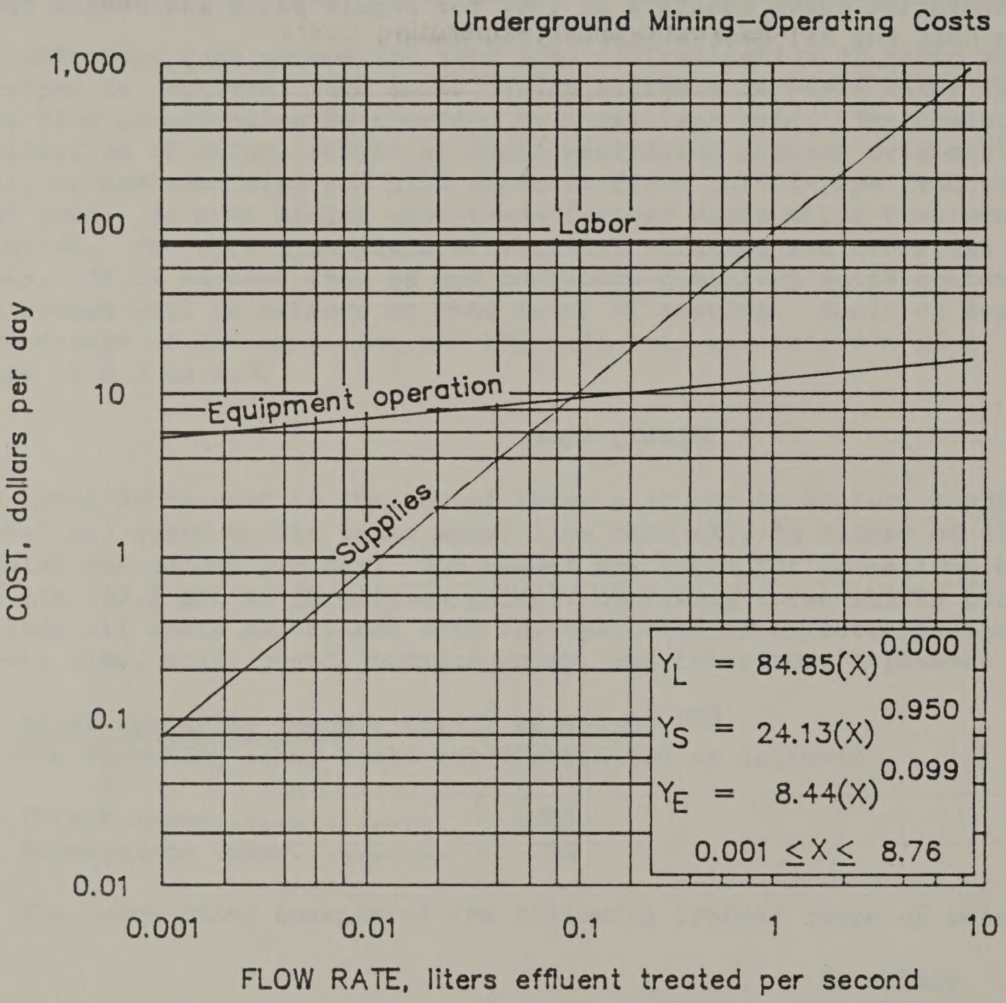
The supply costs consists of electric power, water, and chemicals and lime in the following proportions:

	Small (0 to 8.76 L/s)	Large (8.76 to 876 L/s)
Electric power............	3%	2%
Water.....................	80%	89%
Chemicals and lime........	17%	9%

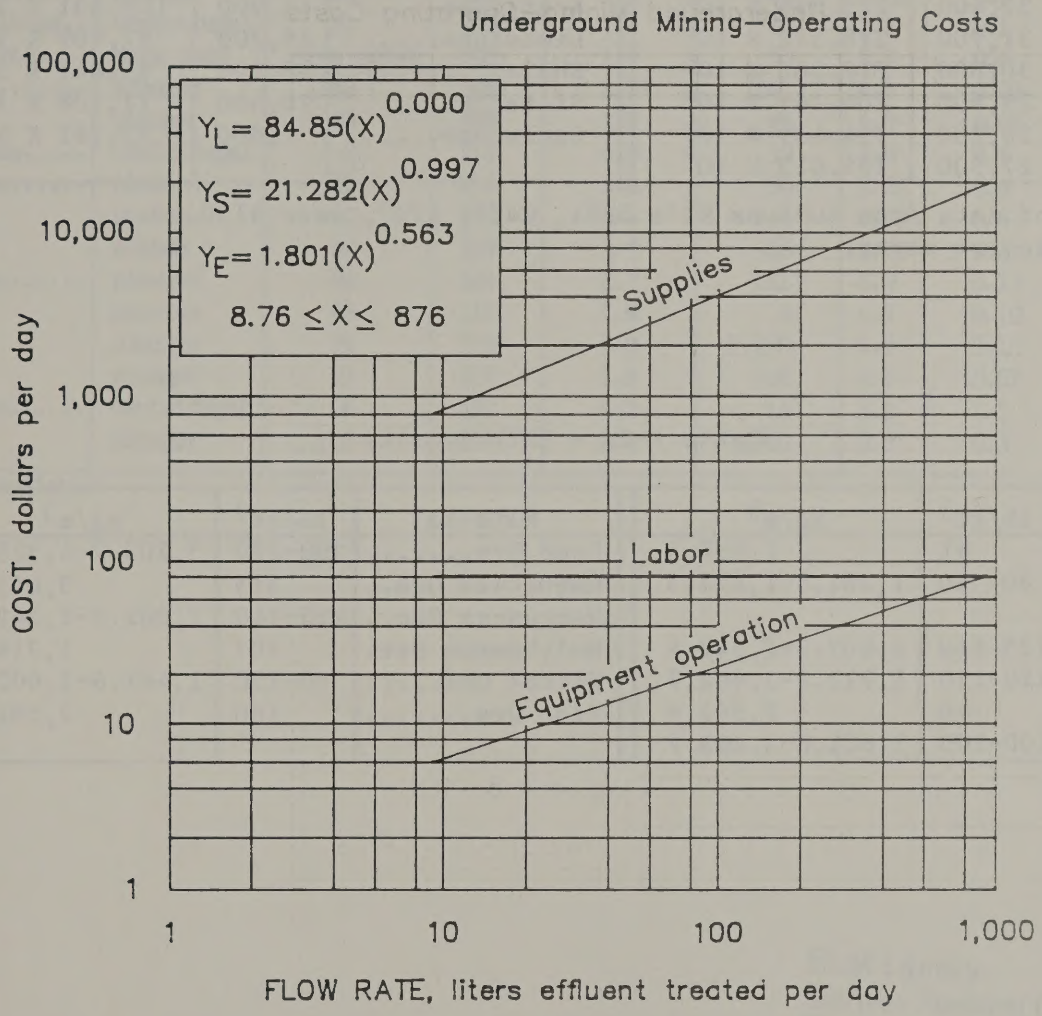
(E) Equipment Operating Costs $(Y_E\ 0.001\text{-}8.76\ L/s) = 8.44(X)^{0.099}$

$(Y_E\ 8.76\text{-}876\ L/s) = 1.801(X)^{0.563}$

The equipment operation curve consists of 100% for repair parts and covers the daily operation cost for all neutralization equipment.



5.2.7.4.2.a Wastewater treatment
NEUTRALIZATION



5.2.7.4.2.b Wastewater treatment
NEUTRALIZATION

APPENDIX.--REFERENCE TABLES

Table A-1. - Average compressive strength of some common rock types[1]

(Compressive strength determined parallel to bedding where applicable)

Rock type	psi	[2]Pa	Rock type	psi	[2]Pa
Tactite.......	57,000	393.015 X 10^6	Slate.........	27,100	186.855 X 10^6
Diorite.......	33,000	227.535 X 10^6	Monzonite.....	16,300	112.389 X 10^6
Marble........	32,400	223.398 X 10^6	Argillite.....	15,900	109.631 X 10^6
Granite.......	31,700	218.572 X 10^6	Limestone.....	14,200	97.909 X 10^6
Quartzite.....	30,800	212.366 X 10^6	Shale.........	13,900	95.841 X 10^6
Chert.........	29,900	206.161 X 10^6	Siltstone.....	10,400	71.708 X 10^6
Basalt........	28,200	194.439 X 10^6	Sandstone.....	7,800	53.781 X 10^6
Hematite......	27,500	189.613 X 10^6			

[1] Compilation of data from BuMines RI's 3891, 4459, 4727, and 5130.

[2] Newtons per square meter.

Table A-2. - Bulk density

Material	lb/ft^3	kg/m^3	Material	lb/ft^3	kg/m^3
Asbestos Ore...	81	1,297.5	Lead Ore.......	200-270	3,203.7-4,325.0
Bauxite Ore....	80- 90	1,281.5-1,441.5	Magnetite Ore..	315	5,045.8
Chrome Ore			Manganese Ore..	125-140	2,002.3-2,242.6
(Chromite)....	125-140	2,002.3-2,242.6	Molybdenum Ore.	107	1,714.0
Copper Ore.....	120-150	1,922.2-2,402.7	Nickel Ore.....	90-150	1,441.6-2,402.7
Ilmenite Ore...	140	2,242.6	Zinc Ore.......	160	2,562.9
Iron Ore.......	100-200	1,601.8-3,203.7			

Table A-3. - Major slurry pipelines and their characteristics

Material	Pump Type	Length, km	Diam., mm	Velocity, m/sec	Pressure, kg/cm^2	S.G.	Particle Size, mm	% Solids	Flow, L/min
uxite........	plunger	73	200	2.1	NA	2.3	0.4	55	3,785
ach sand.....	centrifugal	3	508	4.6	21	2.70	2.3	35	52,990
al...........	piston	174	273	1.5	86	1.40	1.2	52	6,245
	piston	440	457	1.7	126	1.40	2.3	50	17,030
	piston	1,667	965	1.7	NA	1.40	2.3	50	64,350
pper conc....	plunger	27	168	1.7	141	4.3	0.2	65	1,820
	plunger	111	114	1.5	162	4.3	0.15	65	520
	plunger	61	143	1.8	148	4.30	0.15	65	720
lsonite......	plunger	116	168	1.2	144	1.05	4.7	46	1,250
ld tailings..	centrifugal	11	200	1.4	80	2.7	0.1	45	3,400
ld quartz....	Mars pump	mine hoist	200	1.4	80	2.7	0.6	50	2,200
matite.......	plunger	403	508	1.7	141	4.9	0.07	60	18,930
	plunger	48	508	1.7	NA	4.9	0.07	60	18,930
on sands.....	centrifugal	8	219	4.9	33	4.9	0.6	60	8,710
mestone......	piston	27	194	1.8	90	2.70	0.6	60	3,100
	piston	92	273	1.4	148	2.70	0.4	61	3,260
	piston	10	219	1.5	68	2.70	0.3	60	2,350
gnetite......	plunger	86	244	1.7	141	4.9	0.15	60	4,390
	gravity	48	219	1.8	4	4.9	0.10	60	4,160
	plunger	26	273	1.8	1,230	4.9	0.10	60	6,430
	plunger	32	219	1.8	101	4.9	0.07	60	4,160
osphate......	centrifugal	6	457	4.2	14	3.2	1.2	40	37,850
	plunger	113	244	2.1	1,900	0.3	0.3	65	7,950

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